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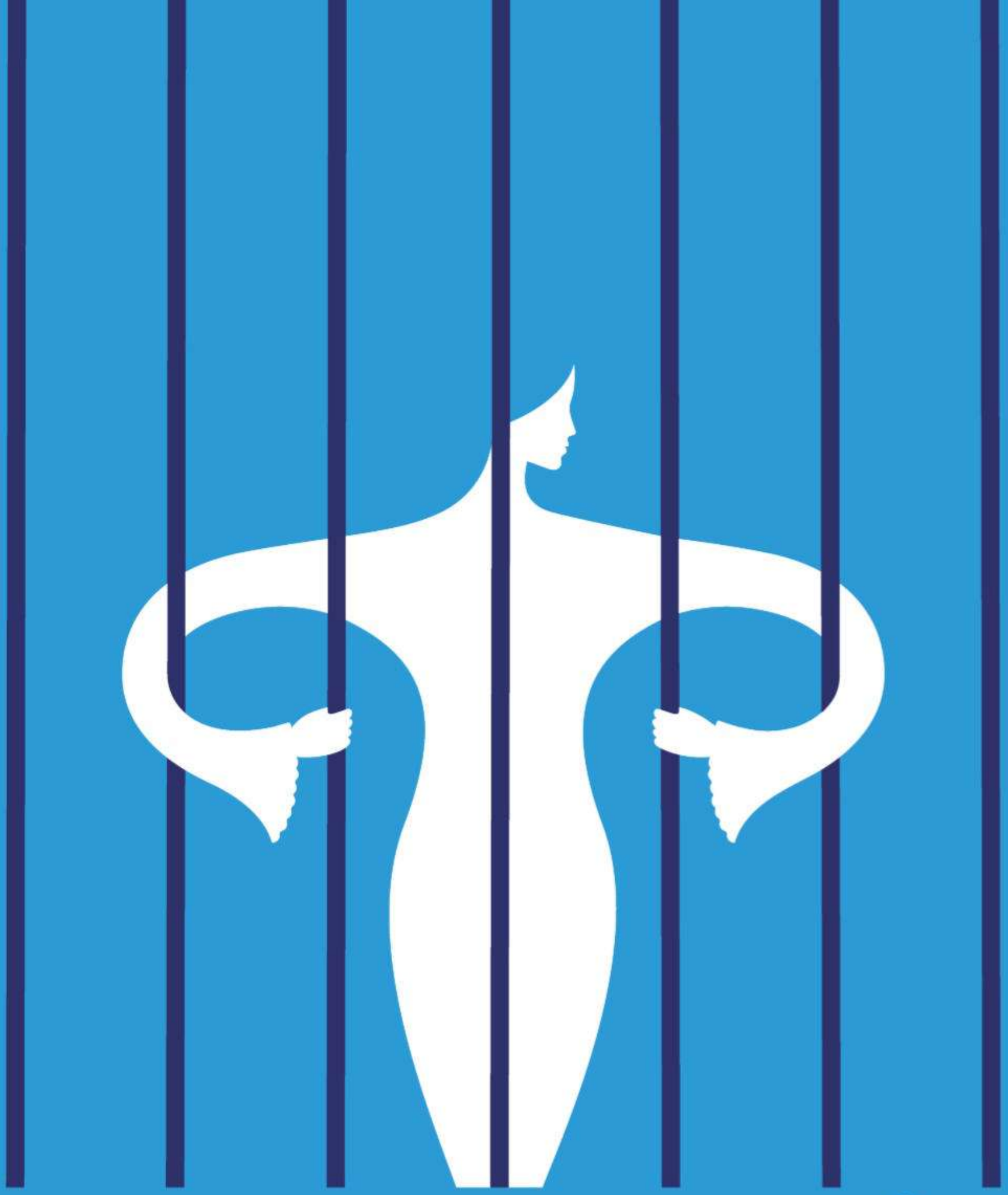

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A talk on the wild side

Hear wildlife conservationist and presenter Chantelle Lindsay recount how her love for nature has shaped her career. At New Scientist Live on 12 October at London's ExCeL Centre, she will cover nature's benefits for mental health and explore how we can all take steps to leave this planet a better place than we found it.

newscientist.com/nslmag

Tour

How to get more from your time: Thailand

Join author and experience designer James Wallman in Thailand as you learn how to spend your time better. Experience bustling cities and remote wilderness in an immersive tour designed – using the latest findings in the art and science of experience – to be joyous, surprising and transformational. This eight-day tour starts on 30 September and costs £2399.

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Podcast

Weekly

The team discuss whether climate change is accelerating faster than previously predicted. They reveal why flies are incredibly valuable to all kinds of ecosystems. There is a sequel to our previous reporting on the mysterious GPS jamming happening in parts of Europe. Plus, how heart attacks are connected to emotions, and a newly discovered sensory organ in praying mantises.

newscientist.com/nspod

A2RL

Pedal to the metal AI-controlled racing cars at the Yas Marina circuit

SHUTTERSTOCK/ORIOL QUEROL

Immersive travel Visit an elephant rehabilitation centre in Thailand

Video

AI-driven race cars

New Scientist video editor David Stock headed to the Yas Marina racing circuit in Abu Dhabi, United Arab Emirates, to watch driverless cars go head-to-head. Guided by autonomous artificial intelligence software, the cars had to complete the course in the fastest time, overtaking opponents and making strategic decisions without any human intervention.

youtube.com/newscientist

Newsletter

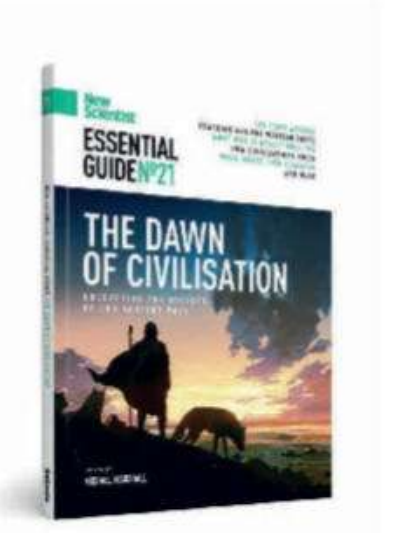
Hubble trouble

Space reporter Leah Crane takes a deep dive into one of the most controversial numbers in cosmology. The Hubble tension is a conflict between two different ways that we measure how fast the universe is accelerating, but it now seems that this decades-old discrepancy may have been resolved.

newscientist.com/launchpad

Podcast

"The extreme heat of 2023 has broken previous records by a wide margin"



Essential guide

Where are the origins of humanity? When did civilisation begin and what does the future of society hold? Uncover the secrets of the past in this *New Scientist Essential Guide* covering all that we know about the arc of human ingenuity. Now available to read in the app or buy in print from our online shop.

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Holy SH**!

Or perhaps that should be "Unwholly SH21"? Because to mark the 10th anniversary of our five-day chronometer movement, Calibre SH21, we've subjected it to open-heart surgery. Between The Twelve X (Ti)'s front and rear sapphire crystals, we've re-forged and skeletonised components with custom-made, diamond cutters. Then sculpted them to a precise, polished finish using re-programmed state-of-the-art CNC machinery. This industrial evolution extends to the outside with a 41mm case made from Grade 2 and Grade 5 titanium. Its top ring is rhodium. And it premiers a new micro-adjustable bracelet. When you find out how much it costs, we swear you'll love it. (And maybe utter the odd expletive yourself.)

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Time for a clean-up

We must stop "forever chemicals" becoming a forever problem

YOU are probably aware of the term "forever chemicals", if not entirely clear on the specifics. What they are is a class of around 16,000 artificial compounds called PFAS that break down very slowly, if at all, in the environment and our bodies. They are extremely useful, but also a potential hazard to wildlife and human health. After more than 80 years of widespread and often unconstrained use, PFAS pollution is more or less everywhere, from the soil on our farms to the rain that waters them. In all likelihood, you have a detectable amount of these chemicals in your body.

A growing body of research has linked exposure to some types of PFAS to harmful effects, such as kidney disease, immune dysfunction and certain types of cancer. Just a few parts per trillion of some forms accumulated over time is enough to be detrimental. Moreover, exposure is more or less unavoidable. Skipping greaseproof packaging or filtering tap water may limit acute exposure, but there are many other contamination routes. In any case, for most of us, it is already too late.

"There is evidence that producers have known for decades that the chemicals could be harmful"

How did we let it come to this? To some extent, society is reaping what it sowed by allowing so many novel chemicals to be released without a proper system to test their safety first. That has to change, and not just for PFAS. Time and again we find, too late, that industrial chemicals are harmful – as now seems the case with those in some climbing shoes (see page 10) – while allowing the firms that make them to carry on business as usual.

There is nothing illegal in that. Nonetheless, the PFAS industry has been grossly irresponsible. There is good evidence that some producers have known for decades that the chemicals could be harmful, but actively obfuscated that knowledge.

As the science of PFAS advances (see page 36), there is optimism that they can be replaced, as well as rounded up from the environment and destroyed. But the bill will be vast. It isn't unreasonable to ask the firms that invented and profited from these products to foot at least part of it. ▮

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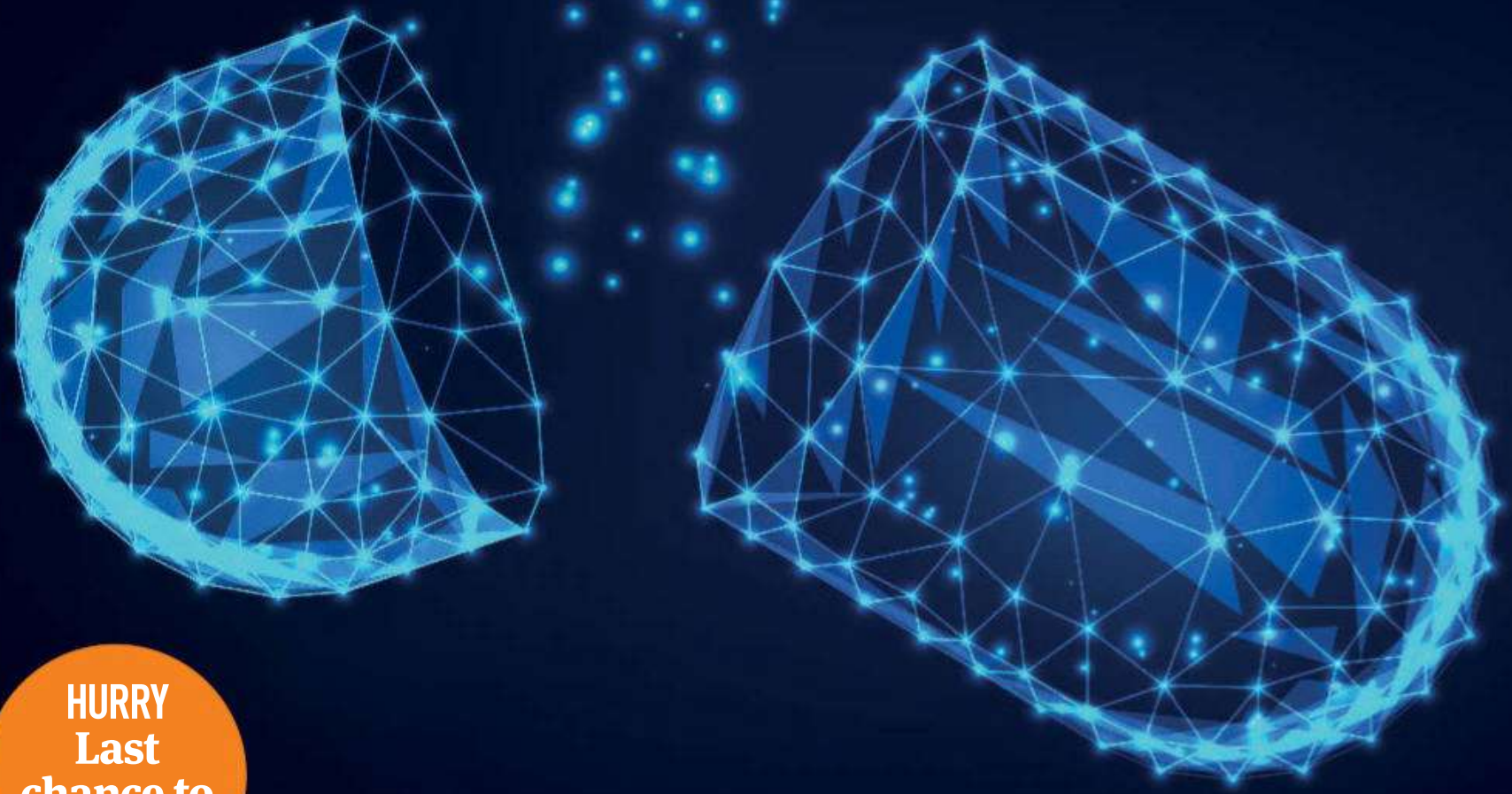

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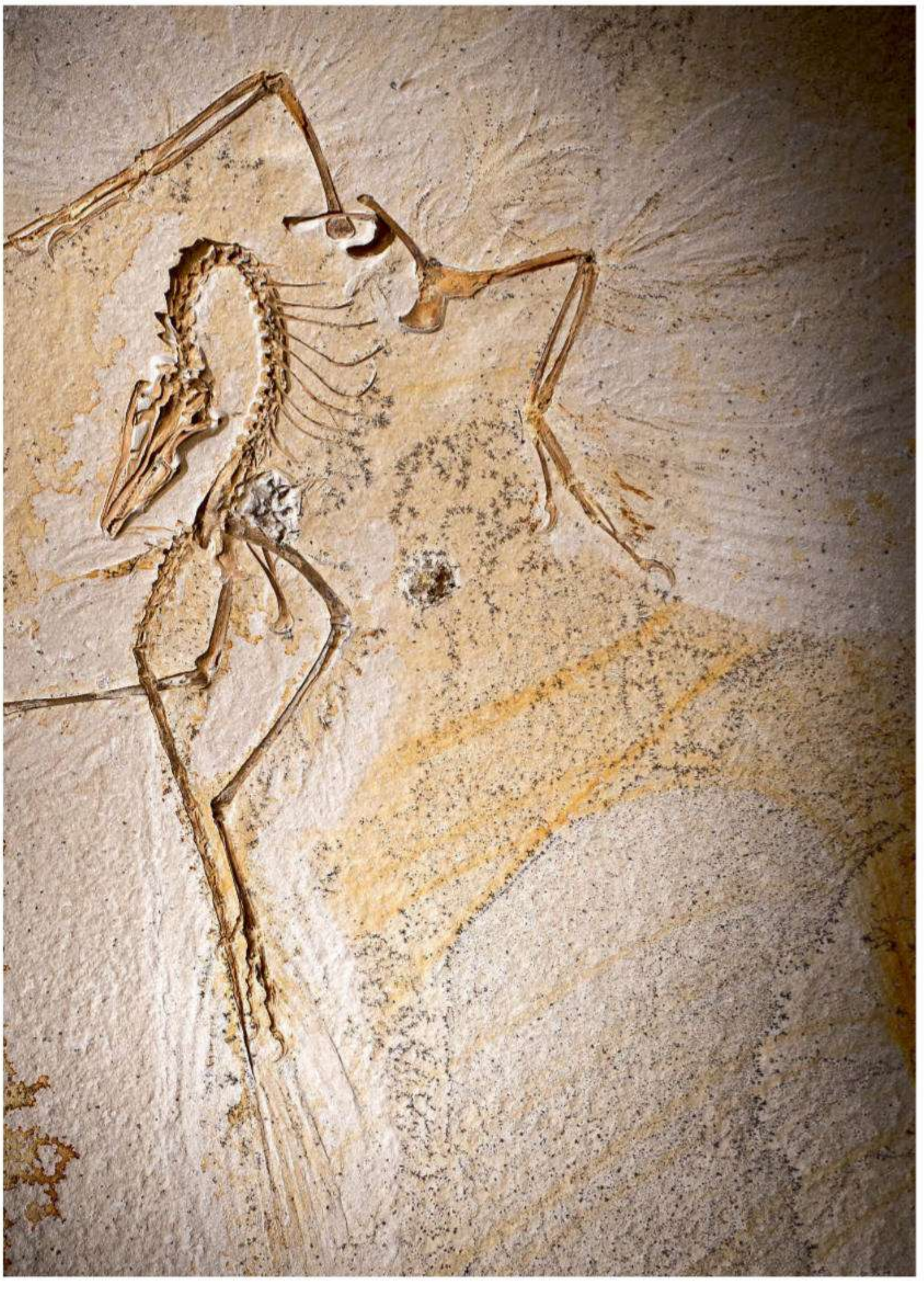

DELANEY DRUMMOND/FIELD MUSEUM

Palaeontology

Flying dinosaur alights in Chicago

THIS majestic *Archaeopteryx* fossil has just gone on display at the Field Museum of Natural History in Chicago, Illinois, and is the first specimen of the crow-sized, bird-like dinosaur in a public collection outside of Europe. The museum acquired the fossil from private collectors in Switzerland and spent two years preparing it, working the surrounding rock to reveal the fossil's details.

Health

Lack of US bird flu tracking in cows may raise risk of human infection

Grace Wade

PUBLIC health experts warn that not enough is being done to contain the spread of a bird flu virus in US dairy cows, increasing the risk of the disease spilling over into people.

More than a month has passed since the US Department of Agriculture (USDA) first announced that dairy cattle in several US states had tested positive for a bird flu virus called H5N1, which has killed millions of birds and hundreds of mammals worldwide. The virus has since been detected in 36 dairy herds across nine states – and in one dairy worker in Texas, who has fully recovered. Yet this is likely to be just the tip of the iceberg.

"We don't really have a great handle on the extent of the outbreak," says Seema Lakdawala at Emory University in Atlanta, Georgia. That is because inadequate surveillance has left us in the dark about how far the virus has spread and how it is being transmitted, she says.

The USDA announced at the end of April that it would only require cows to undergo testing if they are moving across state lines. Otherwise, it suggests farmers voluntarily test cattle if they show signs of bird flu.

At issue is the fact that farmers have no incentive to do testing, especially because they risk being stigmatised if their herd is found to be positive, says Fred Gingrich at the American Association of Bovine Practitioners (AABP) in Ohio.

This is in sharp contrast to protocols for H5N1 in poultry. Here, the USDA reimburses farmers for culling birds to prevent the disease from spreading. This encourages them to report an outbreak early and contain it quickly.

JOHNNYGREIG/GETTY IMAGES

The US could increase bird flu surveillance by testing milk on farms

Other than covering the cost of testing for the virus, the USDA doesn't reimburse dairy farmers in any capacity – not even for the cost of having a vet come out and collect samples, says Gingrich.

Justin Smith at the Kansas Department of Agriculture echoes these frustrations, noting that farmers must shoulder any production losses, including if their farm is shut down for investigation. The AABP has voiced these concerns to the USDA, but it is most likely that any increase in funding would require congressional approval, says Gingrich.

Beyond creating an incentive for farmers to test sick cattle, the government could increase surveillance by testing samples from bulk milk tanks. These pool raw milk from all the cattle on a farm. "If we can test that bulk tank, we're basically testing all the cows," says Gingrich. Right now, this can only be done with a dairy farmer's consent.

The USDA didn't directly respond to *New Scientist*'s questions about whether it will increase H5N1 surveillance efforts. Instead, a spokesperson said that the "USDA will continue to engage with producers, veterinarians, public health officials, agricultural officials and industry representatives to assess the best path forward".

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Number of US dairy herds in which H5N1 has been detected

"I don't like doomsday scenarios, but this is the worst it has ever been for H5N1. This is when we all need to be very concerned because we have the potential of a lot of people getting exposed to [the virus], becoming sick and it adapting in humans," says Lakdawala. "I would have expected, given what we know now, a stronger response." ▮

Quantum computing

Schrödinger's cat could help cut quantum errors

Karmela Padavic-Callaghan

A QUANTUM bit inspired by Schrödinger's cat is able to perform without errors for an unusually long time. This may make it a promising building block for future quantum computers.

Researchers have long believed that quantum computers can solve problems that are impossible for conventional machines, but there have been very few demonstrations of such capability so far. This is because quantum computers tend to make errors as they compute.

Zaki Leghtas at the École Normale Supérieure in France and his colleagues, in collaboration with the quantum computing start-up Alice & Bob, have now created a quantum bit, or qubit, that runs for longer without bit-flip errors – equivalent to the digital 0s in a standard computer spontaneously becoming 1s, or vice versa.

The researchers made their qubit by trapping light in a small hole on a chip filled with tiny circuits made from perfectly conducting – or "superconducting" – wires. The light could oscillate back and forth in two ways inside the hole. But instead of forcing it to oscillate one way only, the team made it do both – creating a quantum "superposition" similar to the one involving the both-alive-and-dead cat in Erwin Schrödinger's thought experiment. This qubit is, accordingly, called a "cat qubit".

The cat qubit can function for 10 seconds without bit-flip errors, which is 10,000 times longer than in any past experiment, says Leghtas (*Nature*, doi.org/mvgz). Using these cat qubits could cut the number of qubits needed for error-correction by about 10 times, he says.

"This is really cool," says Christian Andersen at the Delft University of Technology in the Netherlands, but while 10 seconds between bit-flips is a long time for a qubit, there are other types of errors too, he says. ▮

Origins of life

Geysers may have created protocells

Simulations show cycles of pressure could generate cell-like structures and even simple proteins

Michael Le Page

CELL-LIKE structures containing simple proteins and even pores in the membrane around them have been created in lab experiments aimed to mimic the conditions found in the crust of early Earth.

"We start with very primitive chemicals, and we obtain something with increasing complexity," says Christian Mayer at the University of Duisburg-Essen in Germany. "We believe that this system is very interesting to look at when it comes to the origin of life."

The starting chemicals include simple fatty substances and amino acids – the building blocks of proteins – thought to have been present in the crust of early Earth. Such chemicals have been found inside 4-billion-year-old quartz rocks, says Mayer.

He and his colleagues put these chemicals in a container of water with carbon dioxide gas at a pressure of about 7.2 megapascals, the kind of conditions that might have been found in cracks and faults about a kilometre deep in the crust.

The team then varied the pressure slightly thousands of times. This kind of pressure cycling can happen in geyser systems and may have occurred on early Earth due to tidal forces, says Mayer, who recently presented the team's findings at a meeting of the European Geosciences Union in Vienna, Austria.

When the pressure goes up, it makes the CO_2 dissolve fatty substances. When the pressure goes down, the fatty substances that have a water-attracting part as well as a water-repelling oily part spontaneously form cell-like spheres, or vesicles, with bilayer membranes similar to those found in living cells.

Some of the amino acids also join together to form simple proteins called peptides. So far, the team has found peptides up to eight amino acids long.

The vesicles and peptides usually break up in the next pressure cycle. But sometimes peptides with water-repelling properties get incorporated into the membrane. This protects the peptides, which then accumulate over multiple cycles. A few of these incorporated peptides straddle the membrane and stabilise it, allowing some vesicles to survive for several pressure cycles.

Pressure changes happen below geysers, like this one in Iceland that is about to erupt

LEONID ANDRONOV/ALAMY

One peptide found in recent experiments can even clump together in groups of six to form pores in the membrane through which water and ions can flow. This can reduce pressure differences and prevent the vesicles from bursting. These processes interact in a way that means the system becomes more and more complex, and more functional, says Mayer.

It is thought life began with RNA molecules that could act as enzymes and replicate, a stage known as the RNA world. "These vesicles could have been the ideal environment where the RNA world could have started," he says.

"I find the work very interesting and certainly important," says Nora Hänni at the University of Bern, Switzerland. But we can't be sure if it reflects the chemicals and conditions on early Earth, she says. ▮

Space

China launches Chang'e 6 to the moon's far side

THE Chang'e 6 spacecraft is heading to the moon to bring back samples from its far side. The Chinese mission blasted off on 3 May from the Wenchang Space Launch Center.

If Chang'e 6 is successful, it will mark China's second sample-return mission to the moon and the first time dust from the lunar far side has been brought back to Earth.

Landing on the far side of the moon, which never faces Earth, is more complicated than doing so on the near side. We can send signals directly to spacecraft on the near side, but landing on the other side requires communications satellites to relay signals around the moon. In preparation for this and other missions, China has placed two such satellites into lunar orbit.

The Chang'e 6 spacecraft was built as a backup for Chang'e 5, which sent samples back from the near side of the moon in 2020. Chang'e 6 was still travelling as *New Scientist* went to press, but on reaching lunar orbit, a lander and ascent module should detach and drop to the surface, targeting a crater near the south pole.

XINHUA/SHUTTERSTOCK

The Chang'e 6 spacecraft blasts off atop a Long March 5 rocket

The lander has four scientific instruments to study the area where it touches down. It is also equipped with a drill and a scoop intended to grab about 2 kilograms of lunar material to be stowed away in the ascent module. The samples could help us understand the history of the moon, Earth and the entire solar system.

Once samples are collected, the ascent module will blast off, reunite with the orbiter and head back to Earth. If all goes as expected, the mission will last 53 days.

Chang'e 6 is the beginning of "phase IV" of China's moon exploration programme, which is expected to consist of two more robotic missions. After that, there are plans to send crewed missions and possibly build a lunar base. ▮

Leah Crane

Technology

Privacy concerns over brain monitors

There could be data sharing problems with many firms that sell consumer neurotechnology devices

Jeremy Hsu

THE makers of some brain-monitoring headsets and other consumer neurotechnology devices may not have adequate privacy and data-sharing policies. An analysis of these policies shows many gather users' neural data and maintain the right to share or sell the information without additional permission from users.

The findings come from a report by the Neurorights Foundation, a research organisation in New York. The foundation looked at 30 companies that sell neurotech devices or services directly to consumers with promised benefits, such as improving sleep quality or promoting mental health. The majority of the firms are based in the US, Canada, the UK or the European Union.

"Our position is that brain data is at least as sensitive as personal health data," says Rafael Yuste, co-founder of the Neurorights Foundation. "Why should people be okay about sharing brain data that can be decoded – if not today then in the future?"

Such consumer devices typically use electroencephalogram (EEG) technology built into a headband or helmet to measure the electrical signals of neurons. A few also rely on infrared light to measure changes in blood oxygen levels.

"Why should people be okay about sharing brain data that can be decoded – if not today then in the future?"

The Neurorights Foundation found that 29 of the 30 companies appeared to have access to customers' neural data without providing meaningful limitations on how they are allowed to share that information. Two-thirds allow for the sharing of customer data and almost another third left this unclear, meaning just one company specifically said it wouldn't share customer data.

Furthermore, only 12 of the 30 companies grant customers both the right to withdraw consent for data processing and the right to request data deletion.

Among several of the firms contacted for comment, a few pushed back against the foundation's report. Sweden-based company Flow Neuroscience told *New Scientist* that it doesn't collect any neural data. A representative noted that its transcranial direct current stimulation device has regulatory approval as a medical device in Europe.

A spokesperson for the Canada-based company Interaxon, which offers the Muse neurotech brand, said the company works with organisations such as the Institute of Neuroethics, a think tank in Atlanta, Georgia, to keep its privacy policies up to date and "to ensure the ethical use of brainwave data".

And Tre Azam, founder of the UK-based company MyndPlay, said it never has access to or stores "brainwave data or any other data" from customers. He described the firm's software as running locally on devices without sending any information to cloud computing servers.

The problem is the absence of US government regulations, says Yuste, in comparison with the data privacy protections of the European Union. But that could be changing: Colorado became the first US state to add privacy protections for brain data in April 2024. The Neurorights Foundation is sponsoring similar legislation in California, which could be a "game changer" if it passes, says Yuste.

Many technologies allow firms to collect revealing information about us, says Daniel Susser at Cornell University in New York, and lawmakers should regulate the consumer surveillance industry more broadly. ▮

Air pollution

Climbing wall users might be breathing in toxic rubber dust

SHUTTERSTOCK/UFABIZPHOTO

Indoor climbing centres may have high levels of air pollution

PEOPLE at indoor climbing walls may be inhaling large doses of potentially toxic chemicals because of their shoes.

Climbing shoe soles are typically made from the same materials as car tyres, which are a major source of air pollution as they wear out.

The rubber in a tyre can contain up to 1000 additives, says Thilo Hofmann at the University of Vienna, Austria. While effects of many of these are unknown, some are toxic.

For example, a 2020 study found that a derivative of the tyre additive 6PPD was killing coho salmon in rivers polluted by road run-off.

In a study that has yet to be peer-reviewed, Hofmann and his colleagues took air and dust samples from two climbing gyms in Austria and further dust samples from two more. The team found high levels of particulate air pollution that exceeded World Health Organization guidelines.

The researchers found nine of the 15 rubber additives they tested for in the air samples and 12 out of 15 in the dust samples. 6PPD was one of the detected compounds.

Climbers could breathe in more of these additives than they would if standing next to a busy road, says the team (ChemRxiv, doi.org/mt4j). Testing the soles of 30 makes of climbing shoes revealed that many contained some of the 15 additive compounds in the soles, with one sole containing all 15, suggesting that climbing shoes are the main source of the detected additives.

The team says that cleaning more often, using HEPA air filters or banning certain shoe models could help minimise exposure. ▮

Michael Le Page

Infectious diseases

Red squirrels were hosts for leprosy in medieval England

Chen Ly

THE DNA of leprosy-causing bacteria has been found in the remains of people and a red squirrel unearthed at medieval sites in the UK. This makes this rodent the infection's earliest known non-human host.

SHUTTERSTOCK/VOJTA HEROUT

Red squirrels in the UK can still carry the bacterium that causes leprosy

In 2016, scientists found that red squirrels (*Sciurus vulgaris*) around the UK carry *Mycobacterium leprae*, a bacterium that causes the chronic disease leprosy. The strain found in the squirrels was similar to ones that infected people in England more than 700 years ago.

To investigate further, Sarah Inskip at the University of Leicester, UK, and her colleagues examined the remains of 25 people uncovered at the site of a medieval hospital for people with leprosy in Winchester and those of 12 red squirrels found at a nearby site that was home to at least one fur shop between the 11th and 13th centuries.

Most of the human bones had the characteristic lesions associated with leprosy, and the squirrel bones showed signs of inflammation, another indication of the disease.

By analysing the DNA in the bones, the team found genetic sequences from *M. leprae* in three people and one red squirrel.

"There really was leprosy circulating among medieval squirrels," says Inskip, making the species the earliest reported non-human carrier of leprosy (*Current Biology*, doi.org/mt4d).

The DNA shows that the infection probably spread back and forth between squirrels and people in England in the Middle Ages. ▮

Physics

Black holes lose status as top information scramblers

Karmela Padavic-Callaghan

WHEN quantum objects like black holes interact, all the information they carry becomes scrambled. Now, physicists have calculated a fundamental limit for how quickly this can happen – revealing a surprising demotion for black holes.

When objects fall into these super-dense bodies, some of the information they contain reemerges in the black hole's emitted radiation, but in a highly scrambled form. In fact, physicists had theorised that black holes are the fastest possible scramblers of information. Now, Victor Galitski at the University of Maryland and his team have found that even quicker ones could exist.

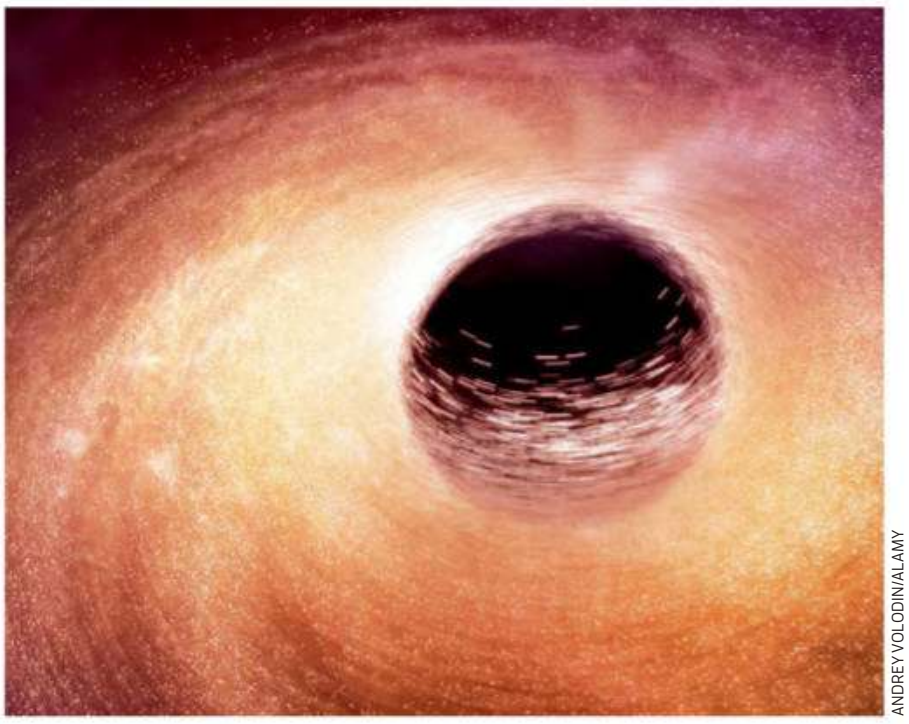
The researchers wanted to calculate the shortest time necessary to fully scramble information in a small quantum system as it interacts with a larger one. For instance, if the small system was a few atoms, the information it contains might be the orientation of the atoms' spins.

To calculate how scrambled the information became, Galitski says they used a

"If black holes aren't the best possible quantum information scramblers, then what is?"

mathematical measure analogous to comparing a drawing in the sand with what that same spot looks like after a few waves hit it. Fully scrambled information was like all the grains of sand that had formed the drawing getting evenly dispersed across the beach.

Using this measure, the team was able to derive an exact speed limit for a quantum system's information scrambling and found that the theoretical highest speed limit was faster than the scrambling speed of a black hole (arXiv, doi.org/mt39).



ANDREY VOLODIN/ALAMY

Matter that falls into a black hole is later radiated away

Nick Hunter-Jones at the University of Texas at Austin says information scrambling is closely related to the strange phenomenon of quantum chaos, which refers to systems that never settle into a simple, even state as time goes on and instead keep changing in intricate ways. Because information scrambling is a symptom by which quantum chaos can often be diagnosed, understanding it better – and for many types of quantum systems at once – opens the doors for new insights into quantum chaos itself, he says.

Hunter-Jones says the new work also opens an intriguing question: if black holes aren't the best possible information scramblers, then what is?

Team member Amit Vikram, who is also at the University of Maryland, says the calculations point to what energies speedy scramblers may have, but it remains unclear whether physicists should look for them where quantum theory and gravity meet, like with black holes, or in laboratory experiments where quantum systems can be engineered from atoms or light.

Juan Maldacena at the Institute for Advanced Study in New Jersey says the latter may be a safer bet – unless some special interactions are missing from mathematical models for how black holes scramble information. He says the limits on black holes' scrambling speed follow from fundamental properties of how gravity makes objects interact. So, the possible existence of even faster quantum scramblers could lead to new insights into how quantum theory and gravity can and cannot combine, which is of great interest to physicists working on a theory of everything. ▮

Health

How anger may raise heart attack risk

Being angry for just 8 minutes causes a change to blood vessels that is linked with heart attacks

Clare Wilson

GETTING angry – even for just a few minutes – can change the functioning of your blood vessels, which may make heart attacks and strokes more likely. The finding could explain why some people experience these events during emotional outbursts.

Previous research has suggested that heart attacks can be triggered by intense emotional experiences. For instance, one study found that in the hour before a heart attack, people were more than twice as likely to have experienced anger or emotional upset as during the same hour-long period the previous day. But the mechanism behind this remained unclear.

To investigate, Daichi Shimbo at Columbia University in New York and his colleagues took 280 young adults who seemed in good health and randomly assigned them to one of four groups. They would experience either anger, anxiety or sadness for 8 minutes, or count upwards until the time elapsed.

Volunteers were asked to think about past events that made them feel the allocated emotion while various aspects of their circulatory health were measured.

ERIC FEFERBERG/AFP VIA GETTY IMAGES

Feeling angry can reduce the capacity of your blood vessels to dilate

This included taking blood samples and measuring blood pressure and the capacity of their blood vessels to dilate in response to a standard procedure where blood flow to the arm is restricted and then allowed to return. Such dilation capacity is thought to be a measure of blood vessel health, with lower dilation capacity having been linked to a higher chance of heart attacks.

"Repeated episodes of a negative emotion may cause irreversible damage"

Perhaps unsurprisingly, none of the volunteers had a heart attack or stroke during this process, but people who were asked to think and speak about a recent event that made them angry had a fall in their blood vessel dilation capacity that lasted for about 40 minutes.

This suggests intense emotions could contribute to cardiac events in people who already have poor health, says Shimbo. "Repeated episodes of a negative emotion may affect cardiovascular physiology over time, causing... irreversible damage," the researchers write in their paper (*Journal of the American Heart Association*, doi.org/mt3p).

The blood vessel response didn't happen for people in the other groups, and there was no difference for any of the groups in the other measurements.

The effects of anger on blood vessel functioning fit with observations that heart attacks occasionally seem to be triggered by intense emotions, says Andrew Steptoe at University College London. However, it isn't necessarily easy for people to stop getting angry, he says. "If people have serious problems, there are anger management interventions, but it's quite difficult, for some of these emotions, to modify them very well." ▮

Climate change

Rising temperatures are a threat to bumblebee nests

BUMBLEBEE nests overheat when temperatures get too high, killing larvae, which might be one of the reasons many bee species are struggling as the world warms.

The global bumblebee population has declined since the 1950s. Researchers have suggested causes from pesticides to habitat loss. Some have also proposed another culprit: climate change.

To investigate, Peter Kevan at the University of Guelph in Canada and his colleagues reviewed studies dating back to the 1800s and found that, regardless of species or region, bumblebees prefer a nest temperature of between about 28°C and 32°C (82–90°F). When nest temperatures surpassed 36°C (97°F), the bees couldn't continue reproducing (*Frontiers in Bee Science*, doi.org/mt3w). Because the bee larvae are more sensitive to heat than adults, one brutal heatwave could kill a nest's next generation.

"It's remarkable that all the way from the high Arctic to the tropics, bumblebees seem to have the same sort of nest temperature requirements," says Kevan. "If it gets too hot... it's quite likely that they will die."

FLPA/ALAMY

If nest temperatures rise too high, it can be fatal for bee larvae

Bumblebees protect growing larvae by fanning their nest with their beating wings. But this may not be enough to compensate for worsening climate change.

Innovations like a robotic climate-controlling "honeycomb" may help commercial honeybee operations, says Kevan, but aren't a practical solution for wild bumblebees.

It is still crucial to consider other threats to bumblebees, and planting native wildflower gardens will help with this, but without also addressing warming, bumblebees may face a harrowing future, says Kevan. ▮

Corryn Wetzel

Astrophysics

Strange signals may come from dead star with a planet

Leah Crane

ONE of the most puzzling phenomena in space may finally have an explanation. It might be caused by the interactions between a "dead" neutron star and a planet in tight orbit around it.

The strange phenomenon is a repeating fast radio burst (FRB). These are series of powerful radio waves blasting at us from distant galaxies. FRB 121102, spotted in 2012, was the first one found to repeatedly send out radio wave blasts. But there is something strange about these repeating FRBs.

"The leading candidates for driving such bursts are compact objects such as neutron stars and black holes, which are all spinning periodically," says Yang Gao at Sun Yat-Sen University in China. As such, we would expect repeating FRBs to blast out signals regularly. But most, including FRB 121102, send out flashes at odd intervals.

Gao led a team that analysed observations of 1145 bursts from FRB 121102. When the researchers divided and categorised the bursts by energy, two periodic patterns emerged – one that repeated every 157 days, and one every 4.6 days.

The researchers interpreted the longer pattern to mean the neutron star causing the bursts is probably orbiting another star every 157 days, which is disturbing the neutron star to produce the first signal. The shorter pattern suggests the neutron star has a planet that circles it every 4.6 days. This planet, if it exists, is probably only about 15 per cent as far from its star as Mercury is from the sun (arXiv, doi.org/mt3r).

Its bombardment by high-energy particles from the neutron star and the influence of its neighbour's magnetic field would make the world very unpleasant, says Gao. "The sky will not be blue, cannot have clouds, will not have beautiful rainbows – instead, [it would have] lightning all the time." ▮

Technology

GPS jamming traced to Russia after European flights suspended

Jeremy Hsu

A GPS jamming attack in the Baltic region that prompted a Finnish airline to pause some flights to Estonia for a month was probably launched from Russia, according to officials and an analyst.

The jamming incidents are part of an ongoing pattern of GPS interference in Europe. A NATO military official told *New Scientist* that the attacks have escalated significantly since Russia's full-scale invasion of Ukraine in February 2022.

"It's really never been a question of whether or not this is Russia – who else could it be?" says Dana Goward at the Resilient Navigation and Timing Foundation, a Virginia-based non-profit group. Goward says that, since December, "we've had more and more observations and analysts determining that yes, it is Russia".

One target of such GPS interference has been the country of Estonia, which shares a border with Russia. Suspected Russian jamming of GPS signals in the airspace above Estonia's capital Tallinn began in 2023 and "increased significantly" at the start of 2024, says Üllar Salumäe at the Estonian Transport Administration. "We receive 20 to 30 reports from different aircraft daily about GPS jamming," he says.

1600

Number of aircraft affected by a GPS jamming attack in March

Such jamming hasn't significantly affected flight safety at Tallinn Airport because of alternative navigational aids on the ground and radar coverage that help to guide aircraft, says Salumäe. But a smaller airport in Estonia's second-largest city, Tartu, lacks ground-based aids and air traffic control services to guide incoming and outgoing aircraft.

That is why GPS interference forced two flights operated by Finnair – Finland's flag carrier airline – to abandon their landing approaches at Tartu Airport and turn back on 25 and 26 April. The airline has since decided to suspend flights between Tartu and the Finnish capital of Helsinki until 1 June.

Now an open-source intelligence analyst using the pseudonym Markus Jonsson has traced the GPS jammer by mapping the "radio horizons" – essentially, circles representing the jammer's maximum range – for each affected aircraft where they first reported the jamming. The area with the highest density of intersecting radio horizons – the most likely source of the jammer – is near Saint Petersburg, Russia (see map, below).

Estonia's minister of foreign affairs, Margus Tsahkna, described the latest GPS jamming incidents in Estonia as a "hybrid attack" by Russia and said that the government would raise the issue with the European Union and NATO.

Another transmitter that analysts have geolocated to Kaliningrad – a Russian enclave between Lithuania and Poland – has been frequently jamming GPS signals in the airspace above Poland, Sweden and Germany. It launched a 63-hour attack on GPS signals that impacted more than 1600 aircraft over Europe in March. GPS interference has also affected ships operating in the Baltic Sea.

"Every place else on the globe that this is happening to any degree – Ukraine, the Middle East, Kashmir and Myanmar – people are shooting at each other," says Goward. "So I think it's incumbent upon folks to resolve this before it devolves into an aircraft or ship accident, or people shooting each other." ▮

Likely location (orange) of a GPS jammer hitting flights over Estonia

@AUONSSON/TWITTER DATA: AIRPLANES.LIVE (CC-BY-SA)

Environment

Is climate change accelerating?

The record-breaking heat of 2023 has prompted disagreement among climate scientists, with some saying it shows Earth may have entered a new period of warming, finds **Madeleine Cuff**

FOR almost a year now, the planet has been in uncharted territory. Since June 2023, every consecutive month has been the hottest on record. Antarctic sea ice has been tracking at near-record lows for months. Sea surface temperatures have stayed at record highs since this time last year. And in the midst of this, the world has been gripped by floods, droughts, storms and heatwaves.

With each consecutive month of record-breaking temperatures, concerns are growing that the world has tipped into a new phase of warming. But is climate change really accelerating?

Like everything to do with climate change, it is complicated. What is clear is that the extraordinary heat of 2023 has climate scientists rattled – and even, in a rare example of disagreement across the field, butting heads.

"2023 was unusually warm, and we still don't have a good explanation for why," says Zeke Hausfather at US non-profit Berkeley Earth. "That is worrying in its own right."

"I've been using the word 'disquieted'," says Gavin Schmidt at NASA. "We like to have answers, we like to be able to explain things, especially important things like the climate. And up until last year, we were pretty good at explaining things."

LOUISA GOULIAMAKI/AFP VIA GETTY IMAGES

Extreme heat in July 2023 led the Hellenic Red Cross to give out water in Athens, Greece

Scientific schism

The basic facts aren't in contention: Earth's climate is warming, mostly due to the greenhouse gases we have emitted, and it will continue to do so until we reach net zero. But because the climate operates on the scale of decades, not years, interpreting 2023 has caused a schism in climate science circles.

"The sharp uptick in global temperatures last year cannot yet be used as proof of an even steeper acceleration in the rate of climate change," says Colin Jones at the Met Office, the UK's national weather service. "One year does not make a climate."

So, what is going on? Most of the latest climate models predict that the world will indeed warm faster in current and future decades compared with the rate of warming experienced since the 1970s. That is because although planet-warming emissions of carbon dioxide are still rising, emissions of planet-cooling aerosol gases have been falling as part of a global crackdown on air pollution. Since 2006, China's emissions of sulphur dioxide have fallen by more than 75 per cent, for example.

To be clear, this means that climate scientists are in agreement that we should expect an acceleration. The latest assessment from the Intergovernmental Panel on Climate Change suggests the rate of warming up to 2050 will be about 26 per cent faster than that from 1970 to the present day.

Where the disagreement arises is on whether we can already detect an increase in the rate of warming from real-world observations. "It's not necessarily that warming is happening faster than climate scientists expected," says Hausfather. "But it may well be that warming is happening faster than we have seen historically."

0.05-0.1

Degrees Celsius of additional heat in 2023 that are unaccounted for

He says other climate data beyond just average temperatures, such as ocean heat figures, indicate an acceleration is already under way. "There's a consilience of evidence across multiple lines."

Laura Wilcox at the University of Reading, UK, says observations show an increase in the rate of short-wave radiation from the sun penetrating Earth's atmosphere since 2001. "If we are increasing the amount of shortwave radiation that's coming into the climate system, we would expect that to cause a warming."

But there is a catch. Enter El Niño, the weather pattern that develops when waters in the Pacific Ocean warm, which tends to push up global temperatures. "The 2023 warming spike is due to El Niño," says Michael Mann at the University of Pennsylvania.

Jones suggests the record heat in 2023 could be a result of the El Niño pattern increasingly acting as a release valve for excess heat stored in the ocean.

"The ocean has always been accumulating heat, but it's been accumulating more and more," he says. As the ocean becomes more stratified due to colder waters sinking, more of that heat is held in surface waters rather than penetrating into the deep ocean.

"That might mean the heat that is going into the ocean on a slow timescale tends to be residing incrementally nearer the surface. Therefore, when you have an event like an El Niño, which allows heat back to the surface, there's more of it to more readily come back," says Jones.

As a result, these temperature "bumps" from El Niño might become larger in future years. "We're going into difficult territory, there's no question about that," he says. "And it's

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the heat in the ocean that I think is the primary driver."

Others are sceptical that El Niño explains all of 2023's record warmth. For a start, the current El Niño doesn't fit previous events, says Schmidt, with temperature records broken even before it had fully developed. "We saw record warm temperatures in the North Atlantic starting in March, record warm temperatures globally starting in June, record low sea ice starting in July, in Antarctica," he says. El Niño wasn't formally declared until June 2023.

Unexplained heat

If El Niño can't explain the extraordinary warmth of 2023, something else may be going on. Research is under way to assess the impact of additional cooling from volcanic eruptions, for example, and the effects of tougher aerosol pollution rules for shipping. As well as uncertainty about the volume of aerosols in the atmosphere, there could be errors in current assumptions about their cooling impact on Earth, which could account for some of 2023's unexplained heat.

In a press briefing last month, Samantha Burgess at the Copernicus Climate Change Service said that even accounting for impacts from shipping, volcanoes and other factors, researchers can only partially explain the year's record heat.

"When we look at these different contributions, when we look at greenhouse gas concentrations, we can say that has contributed about half of the warming that we saw in 2023, from the previous warmest year," she said. "When we look at other contributing factors, including natural variability, including aerosols, including the solar cycle, that also contributes about a third of the remainder. So we are missing somewhere between 0.05 to 0.1 of a degree [Celsius] of the additional heat that we saw in 2023."

The puzzle may not be resolved until later this year, when El Niño is expected to fade. If temperatures also dip, that will be a strong hint that El Niño was to blame – but if not, there is the possibility that the world has entered a new phase of climate change with impacts beyond those scientists have predicted.

"If the anomaly does not stabilize by August – a reasonable expectation based on previous El Niño events – then the world will be in uncharted territory," Schmidt wrote in a commentary for *Nature* earlier this year. "It could imply that a warming planet is already fundamentally altering how the climate system operates, much sooner than scientists had anticipated."

To date, climate models have been very accurate at forecasting how much global warming a given level of greenhouse gases will produce. However, there is still a lot of uncertainty about climate feedbacks, which could result in more greenhouse gases in the atmosphere than currently expected – for instance, if forests die off at lower levels of heat and drought than predicted.

"2023 was unusually warm, and we still don't have a good explanation for why"

However, scientists are nervous about sounding the alarm too early. They stress that even though 2023 was an unusual year, it still lies within the range predicted by long-term models. And it will take years before any long-term trend becomes clear.

"There is a risk of jumping to conclusions here," says Hausfather. "We don't have much data yet, and we don't have great answers. We can't rule out the possibility that 2023 was just a short-lived internal variability that is not going to persist." ▮

SNAPSHOT/FUTURE IMAGE/U STAMM/SHUTTERSTOCK

Exceptional rainfall made the river Leine in Germany burst its banks at the end of 2023

Even hotter summers

Future heatwaves in Europe will be even more sweltering than feared. The regional climate models relied on by planners underestimate summer heat because they don't factor in more intense sunshine due to falling air pollution.

When Dominik Schumacher at ETH Zürich in Switzerland and his colleagues compared the observed summer warming in Europe between 1980 and 2022 with the projections of global and regional climate models, they found the regional models underestimated the actual warming by more than 1°C, on average. Global models did better, only underestimating by an average of around 0.5°C.

When the researchers excluded the effects of changes in air circulation patterns that are bringing more heat to the region, this brought the global models nearly in line with the observed warming, but regional models still underestimated changes by more than half a degree on average.

Most regional models also didn't account for the sunlight intensity increasing in Europe as levels of air pollutants decline.

This means the regional models are underestimating how much warmer European summers will be by 2100 by more than 2°C, say the researchers. The underestimation of heatwaves is even greater, because during these events there are usually clear skies and even more sunshine than normal, says Schumacher, who presented the finding at a meeting of the European Geosciences Union in Vienna, Austria. Michael Le Page

Chemistry

Boundary between water and air is three molecules thick

Karmela Padavic-Callaghan

WE HAVE finally pinned down the precise thickness of the barrier between water and air – and it is made of about three layers of water molecules. The finding could offer insights into atmospheric science or help ramp up renewable energy production.

"We have water in our human body, we have water in the atmosphere. Water is everywhere, but there's still a huge lack of knowledge about water," says Martin Thämer at the Fritz Haber Institute of the Max Planck Society in Germany.

Water molecules are usually oriented randomly and are weakly attracted to each other, but Thämer and his colleagues knew that those on the surface take on a special alignment because they can't interact with air molecules above them.

To find out just how far down this goes, the researchers vibrated water molecules with two laser beams and analysed changes in the properties of the reflected light, such as frequency.

It took about 60 hours of measurements to obtain a precise result, says team member Alexander Fellows at the Fritz Haber Institute. They found that the boundary between air and water must contain roughly three layers of water molecules, a region less than a single nanometre thick (arXiv, doi.org/mts8).

Understanding this boundary could help us figure out processes like catalysis reactions in chemistry, how atmospheric gases dissolve into the ocean and efforts to split hydrogen for energy production, says Damien Laage at the École Normale Supérieure in Paris. The new measurement aligns with past theoretical calculations, he says, but no theoretical consensus yet exists for other properties of the air-water interface. ▮

Ecology

Flies make epic migrations that may be vital for pollination

Michael Le Page

WILL LEO HAWKES

Pied hoverflies migrate to the UK from mainland Europe

MANY species of fly migrate for hundreds or thousands of kilometres, often in vast numbers, a research review has shown. These overlooked migrations mean flies may play a key role in many ecosystems, particularly by carrying pollen for long distances.

This could be especially important as the world gets hotter, says Will Hawkes at the University of Exeter, UK, by allowing plants to acquire genetic variants from further afield that may help them survive drought or better resist pests and diseases that thrive in warmer conditions.

Hawkes became interested in insect migrations while researching his PhD on the island of Cyprus in the Mediterranean. "The insects were coming towards us across the sea from the Middle East, and they were getting channelled up this narrow gully," he says. "One day, the peak rate of insect arrival to this 100-metre-wide area of land was 6000 insects per metre per minute – and they were all flies. We had to hide behind our car doors because there were so many insects going through."

This made Hawkes think that fly migrations might be more common than was realised. Now, he and his colleagues have searched through the scientific literature and brought together all the evidence for this.

3000km

Distance migrated by some American hoverflies

In scientific terms, flies are insects with a single pair of wings. This group includes mosquitoes and midges, but not dragonflies and mayflies. The review concludes that fly migration is common. "In terms of the number of individuals, flies are definitely the main insect migrants," says Hawkes.

Hoverflies are the family of flies for which the team found the most evidence of migration. For instance, female marmalade hoverflies (*Episyrphus balteatus*) migrate from as far north as Scandinavia to Spain and North Africa during the autumn, where they lay their eggs. During spring, the hoverflies migrate back more slowly over the course of several generations, following the wave of flowering plants.

A 2022 study showed that some individual American hoverflies (*Eupeodes americanus*) migrate more than 3000 kilometres from Canada to the south-eastern US. This is the longest confirmed fly migration, says Hawkes.

Mosquitoes are another fly family for which there is much evidence of migration. For instance, some migrate between India and Japan, says Hawkes.

Some flies, including the common drone fly (*Eristalis tenax*), have been found to travel more than 100 kilometres while carrying the pollen of at least eight plant species.

When travelling long distances, flies rely on winds to carry them. They may fly as high as 1 or 2 kilometres above the ground while migrating and have been observed in mountain passes at altitudes as high as 5.4 kilometres (bioRxiv, doi.org/mts9).

Erica McAlister at the Natural History Museum in London says the review shows fly migration is more common and important than we realised. "It would be hard to quantify the total impact of these migrations," she says. "Just in terms of the sheer numbers involved, though, their impact must be significant and thus exceptionally important in terms of conservation and food security." ▮

Technology

Social media ads buy votes for €4

Political adverts may swing elections cheaply, finds an analysis of German election results

Chris Stokel-Walker

A POLITICIAN really can increase their popularity by using adverts on social media, and swaying a single voter requires around €4 of advertising spend, at least based on the results of an election in Germany.

Dominik Bär at Ludwig Maximilian University of Munich in Germany and his colleagues analysed more than 21,000 Facebook and Instagram adverts posted by German political parties in the run-up to the 2021 federal elections. "We were interested in how these parties are advertising and how it related to the election outcome," says Bär. The team used Meta's advert transparency website, which records all political adverts on the firm's platforms, and found that the posts were viewed a total of 126 million times.

By using a statistical model to account for confounding factors, such as whether the candidate was an incumbent or not and how much time they spent campaigning, the team found that advertising on social media increased the likelihood that a candidate won an election.

The researchers were able to quantify the impact of social media campaigns, finding that every 200,000 times a candidate's advert was seen, their votes rose by 2.1 per cent. "That this happens at this scale was a bit surprising," says Bär.

Perhaps most importantly,

The votes cast in a German election seem to have been influenced by social media ads

ACTION PRESS/SHUTTERSTOCK

the researchers believe that the results may reflect what happens in other countries where people vote directly for a representative across constituencies. While this is only partially true in the German federal elections, which also include indirect votes through a system of proportional representation, it is similar enough to others, says Bär.

"The election is comparatively large, with more than 60 million eligible voters and candidates from multiple parties across the political spectrum," he says. "The results may thus generalise to other elections."

He adds that the findings are especially pertinent this year, which is full of important elections. "I think this is very interesting now, with the US election coming up in November, but then also the European elections," says Bär.

The researchers looked at how close races were in the 2021 German federal elections and found that the outcome would have changed in 12 out of 299 constituencies if the candidate who came second had received a 2.1 per cent increase in vote share, translating to an average of 500 additional votes. Achieving this swing through online ads would cost about €2000, or €4 per voter (OSF Preprints, doi.org/mt3m). For context, 1785 candidates representing major parties in that election spent a total of some €1.4 million on online ads.

Not everyone is as certain about the findings. "This is one study and an outlier," says Kate Dommett at the University of Sheffield, UK. "I would be cautious about this result."

Dommett says the effect of adverts on votes is of a magnitude greater than found by previous studies of social media-based advertising campaigns. "In general, most studies of political ads' effectiveness show small effects, which are notably smaller than the effects of more traditional communications strategies such as doorstep canvassing or volunteer phone calls," she says. ▮

Zoology

Bump on praying mantis chest is an odd type of tongue

SOME mantises can taste leaves with a newly discovered sensory organ: a strange, bristly bump projecting from their chests.

This "gustifolium" is unlike anything seen in mantises or any other predatory insects, say the researchers who made the discovery. It may have evolved to aid certain mantises' extremely specialised lifestyles.

Some praying mantis species found in Asia and Australia engage in "leaf-planking", flattening their bodies against the underside of leaves as they cling, motionless.

Researchers previously noticed that some leaf-planking species had a curious, circular chest projection. Josh Martin at Colby College in Maine and his colleagues took a closer look at the anatomical oddity in a few Australian leaf-planking species. They used X-rays and microscopes to examine the structure inside and up close.

The gustifolium is studded with 14 to 25 stiff hairs, making it look a bit like a spiky pimple. Inside, the researchers discovered, it is filled with nerve cells.

In lab experiments, the electrical activity of these neurons increased when the structure was exposed to compounds plants release into the air. This suggests the hairs are taste sensors like those found on the feet, legs and mouthparts of other insects. By touching or hovering over their perches, the mantises seem to be tasting those leaves (bioRxiv, doi.org/mtsw).

"The evolution of a unique and specialised organ for sensing is a big deal for an organism," says Martin. So it probably plays a key role, possibly telling the insects what type of leaf they are on or how suitable it is as a hunting perch, he adds.

"By touching or hovering over their perches, the mantises seem to be tasting those leaves"

The finding may have unexpected implications for mantis conservation, says Roberto Battiston at the "G. Zannato" Museum of Archaeology and Natural Sciences in Italy. If the link between leaf-planking mantises and their favourite foliage is species-specific, the disappearance of host plants due to deforestation or other habitat changes could have a "massive impact" on these mantises, he says. ▮

Jake Buehler

Infectious diseases

Measles immunity seems to wane

A modelling study suggests that the level of protection against measles provided by the MMR vaccine falls by a small amount every year, but remains high overall, finds **Clare Wilson**

HAVING two vaccine doses against measles as a child may not always lead to lifelong immunity, despite what is commonly thought, according to new research. Even so, this remains the best way to safeguard against the illness.

The level of protection seems to fall by a very small amount per year, which could explain why a growing number of people are catching measles despite having had two vaccines against it in early childhood. However, even with such a decline, the shots would still be 97 per cent effective by the time people are 30.

The findings come from analysing the pattern of measles cases in recent years in the UK and comparing this with mathematical models in which protection either slowly wanes over time or is lifelong.

Severe impacts

Measles is highly infectious. It usually results in a fever, widespread rash and cold-like symptoms, although occasionally complications can lead to severe impacts such as brain damage. There are other potential effects too. Because the virus infects immune cells, it also causes a weakening of the immune system against other infections, which is known as immune amnesia. This can last from months to years.

Measles cases had been falling worldwide with growing use of the MMR vaccines, which protect against not just measles, but also mumps and rubella, and are usually offered to children as two doses when they are 1 and 3 years old. But falling rates of take-up have led to a resurgence of measles in many countries, including the UK.

Getting both MMR jabs gives a high degree of protection from measles infection, thought to be over 99 per cent a few weeks after the second dose. But it is becoming apparent that more people than expected catch the virus despite double vaccination.

0.1%

Possible rate of decline in resistance to measles per year

There are two potential explanations for this, says Alexis Robert at the London School of Hygiene & Tropical Medicine.

The vaccines might have been ineffective initially, something that happens more often in infants who still have antibodies to measles in their blood passed on during pregnancy, he says. Such antibodies would attack the weakened form of the virus used in the vaccine. Alternatively, the person's immunity to the illness could have waned over time.

Some previous studies looking at blood samples have found that antibodies to measles do fall somewhat as people get older. However, antibodies are only one part of the immune system, so those studies don't reveal if people's protection against infection is indeed declining.

To find out more, Robert's team analysed all the cases of measles reported to Public Health England from 2010 to 2019, noting the person's age and vaccination status.

Over the nine-year period, there was no clear upwards or downwards trend for the total number of cases in England. But a slowly growing proportion of them involved people who had received both MMR vaccines, reaching 7.5 per cent by 2019.

The team ran modelling software to simulate the pattern of cases over time. The models that best fit the real-life data were those that assumed that immunity slowly wanes (medRxiv, doi.org/mttc).

Models that assumed no waning led to far fewer cases in double vaccinated people than the number of cases in real life.

"Only models with waning of immunity could capture the number and age distribution of vaccinated individuals infected by measles," says Robert.

They all suggested that the waning of immunity was slow, however, with a drop of less than 0.1 per cent per year.

"This would mean that individuals at 30 who gained protection after vaccination would still be at least 97 per cent protected against infection," says Robert. "Measles is so infectious that even a slow waning will lead to transmission in some vaccinated individuals."

Booster needed?

It is too soon to recommend that people have a third MMR vaccination because more studies are needed to estimate the impact on transmission, says Robert.

Simon Williams at Swansea University in the UK says the MMR vaccines are still "incredibly safe and effective". "That said, the scientific community are constantly reviewing evidence and if, in the future, evidence grows as to the waning immunity of measles vaccines over the longer term, then no doubt discussions will be had as to the costs and benefits of offering a booster dose at a later age," he says.

Rik de Swart at Erasmus University Rotterdam in the Netherlands says the work is a novel way to investigate the question of immunity waning. "Modelling of infectious diseases can give you information that's simply not possible for the human brain to collect from large datasets," he says.

SHUTTERSTOCK/RAWPIXEL.COM

In most countries, people get two MMR vaccinations when they are children

Space

‘Wall of death’ may help fitness on moon

MOON settlers could exercise by running horizontally around the inside of a circular wall. Just a few laps a day may counteract the health effects of low lunar gravity.

High-speed motorcycles can travel around a circular “wall of death”thanks to friction and centripetal force, but people can’t run quickly enough to do that on Earth, says Alberto Minetti at the University of Milan in Italy.

Now he and his colleagues have shown that with a bungee cord supporting people’s weight to mimic the moon’s gravity, people can complete laps at speeds of about 6 metres per second (*Royal Society Open Science*, doi.org/mtdq). On the moon, a few laps a day would be enough to counter issues of low gravity, such as bone density loss and cardiovascular fitness, he says. **Chen Ly**

SAFRUDDIN

Health

Do dads’ microbes affect infant health?

DECREASING the amount of gut microbes in male mice increases their offspring’s risk of low birth weight. This suggests a father’s microbiome at conception influences infant health.

Jamie Hackett at the European Molecular Biology Laboratory in Rome and his colleagues treated 28 male mice with antibiotics, which decreased the abundance of their gut microbes and shifted the balance of microbial species.

Pups from mice with impaired gut microbiomes had a variety of health issues not found in pups whose fathers hadn’t taken antibiotics before conception. They had lower birth weights and were 2.5 times more likely to have severely stunted growth at 2 weeks old (*Nature*, doi.org/mtsv). This may also apply in humans, but for now we don’t know, says Hackett. **Grace Wade**

Animal behaviour

Orangutan uses medicinal plant to treat facial wound

AN ORANGUTAN has been seen applying the leaves of a plant used in traditional medicine to a cut on its face, seemingly to hasten healing. It is the first case in the scientific record of a non-human animal using a plant with proven therapeutic properties on an open wound.

There have been several previous reports of great apes attempting to self-medicate in other ways. Gorillas, chimpanzees and bonobos sometimes swallow leaves from *Aspilia* plants to get rid of intestinal parasites, for example.

Isabelle Laumer at the Max Planck Institute of Animal Behaviour in Germany and her colleagues noticed a fresh gash on the cheek of a male Sumatran orangutan (*Pongo abelii*) called Rakus, living in Gunung Leuser National Park in Indonesia. “Rakus was injured, most likely in a fight with a neighbouring male,” says Laumer.

About three days later, the team spotted Rakus chewing on the leaves of an evergreen climbing plant called akar kuning (*Fibraurea tinctoria*) and swallowing them. After 13 minutes of feeding, the ape stopped eating and instead smeared the chewed-up plant across his open wound.

“He repeatedly put the plant precisely onto the wound, and no other body parts,” says Laumer.

After four days, the wound had closed up (*Scientific Reports*, doi.org/mt3s). “It was really fast,” she says. Rakus is pictured above, two months after treating his wound.

The healing process was probably accelerated by the plant, says Laumer, which has antibacterial, anti-inflammatory, anti-fungal and antioxidant properties. It is also used by local people to treat malaria and jaundice. CL

Really brief

SHUTTERSTOCK/KOJIN

Why warm drinks taste more alcoholic

Chemists have found a link between the taste of a drink and the shapes formed by its water and ethanol molecules. Compact, pyramid-like structures change to long, chain-like ones as a beverage gets warmer or more alcoholic, which is why whisky tastes stronger if warm (*Matter*, doi.org/mtvn).

Olivine lets cement go carbon neutral

Replacing 35 per cent of the regular cement in a concrete mix with silica derived from an abundant mineral called olivine would produce a carbon-neutral cement. Subbing 40 per cent or more would make the final cement carbon negative (*Royal Society Open Science*, doi.org/mtvt).

Running shoes that make you go faster

Spiked running shoes with a rubbery material between the inner and outer soles, and a stiff plate to improve stability, help people run faster than they do in conventional spikes. The “advanced” shoes are also linked to needing less oxygen when running at a given speed (bioRxiv, doi.org/mtvp).

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Comment

Our mark on the planet

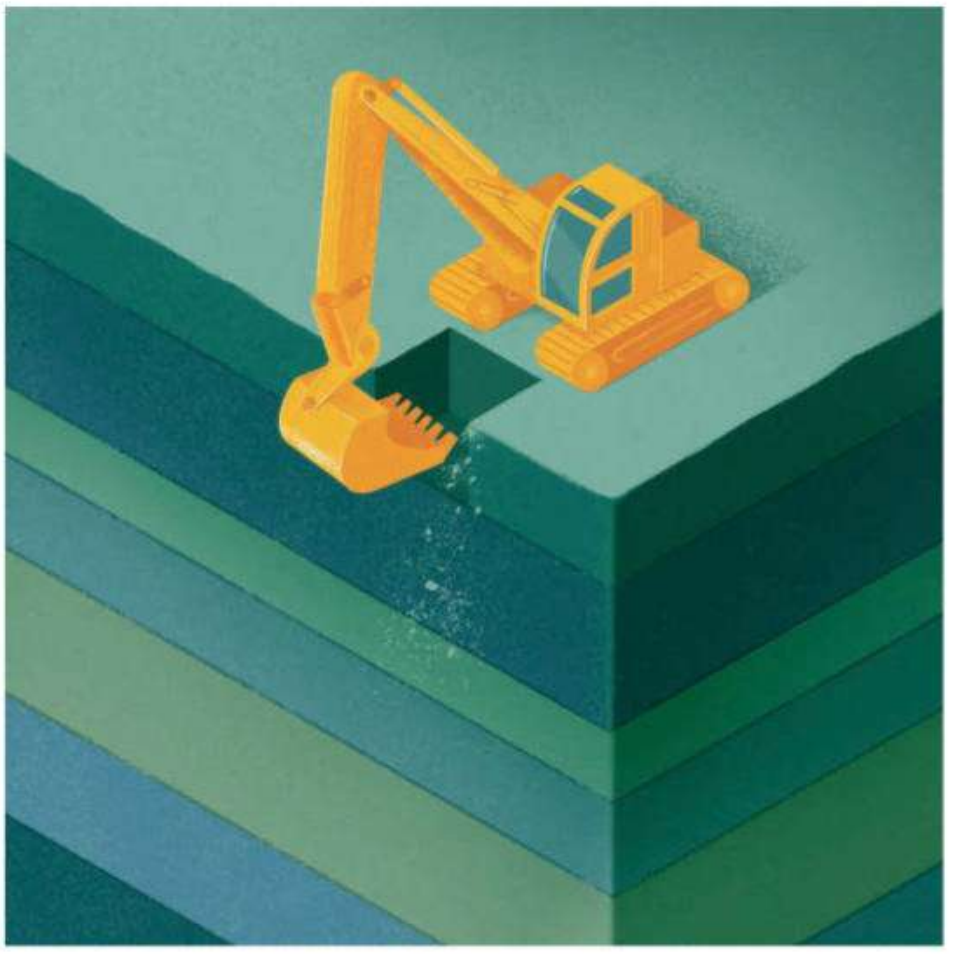
Criticisms of the proposed Anthropocene epoch miss the point. Humanity's impact on Earth is real, whether formalised or not, says **Jan Zalasiewicz**

THE concept of the Anthropocene was born at a scientific meeting in Mexico in 2000, conjured by chemist and Nobel laureate Paul Crutzen. "We aren't in the Holocene any more, we're in... the Anthropocene," he said, as the speed and magnitude of planetary impact by industrialised humanity was hammered home.

A proposal by the Anthropocene Working Group to define the Anthropocene as a geological epoch was rejected this March, after a vote of the Subcommission on Quaternary Stratigraphy, which set up the group. The vote was disputed and flew in the face of the mass of evidence presented, yet it was still countersigned by the International Commission on Stratigraphy and the International Union of Geological Sciences. However, the Anthropocene these bodies targeted was a myth. The real Anthropocene is still, all too clearly, with us.

Crutzen's concept is simplicity itself: there has been a major, irrevocable planetary shift from Holocene to Anthropocene conditions. Graphs of a swathe of parameters, including major greenhouse gases, shift from the near-horizontal tracks they held for millennia to near-vertical lines in the past century or so. The change, most profoundly expressed in the mid-20th century, is dramatic.

But many criticisms of the concept have focused instead on what the Anthropocene isn't: on myths or misconceptions. These lie at the heart of the recent formal rejection.



ELAINE KNOX

There is the charge that the Anthropocene fails to represent all human impacts. True enough – but this wholly misses the point. It is departure from the stable planetary system of the Holocene that is key to recognising a new epoch. This in no way diminishes from the fact that humans have been changing local and regional environments for many millennia. The Anthropocene was never meant to refer to "all things anthropogenic".

It is also said that the Anthropocene is too short to be an epoch; that it is just a blip in Earth's history. It is brief so far, yes – but the past seven decades have fundamentally altered the planet and set it on a new trajectory. Just the climate impacts from using fossil fuels – of which 90 per cent have been burned in the last 70 years – will reverberate for at least tens of thousands of years, driving us into a climate hotter than it has been for at least 3 million years. And many of the biological changes of the past 70 years are permanent, irreversibly scrambling Earth's biogeographic communities as species invasions soar. It is no blip.

Some geologists say there simply aren't enough strata dating from modern times for the Anthropocene to be part of geology. That is wrong. Humans have, since the mid-20th century, been prodigious reshapers of the landscape and movers of rock and sediment: far more so now than natural sediment movers such as glaciers and rivers. Anthropocene strata are already abundant – and they are full of distinctive markers like human-made radionuclides, pesticide residues, metals and microplastics. The geology is real.

These and other myths about the Anthropocene have persisted despite being refuted. This suggests they are reactions more rooted in ideology, or personal philosophy, than in evidence.

Why has the Anthropocene been so misunderstood? Probably because it is deeply uncomfortable, bringing tranquil geological abstractions up against ugly contemporary problems. New scientific knowledge can shake long-held perspectives, so it isn't surprising the Anthropocene has met resistance. But this new epoch is real, whether formalised or not. Recognising our role in speeding Earth towards a radically new future is a prerequisite to coping with the resulting changes.

Jan Zalasiewicz is in the Anthropocene Working Group, which contributed to this essay

No planet B

The real cost of flying

I always add the carbon offset option when buying a flight, but I had a sneaking suspicion I was being greenwashed. Turns out I was right, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm listening to
Serial's new podcast on Guantanamo Bay

What I'm watching
Baby Reindeer

What I'm working on
Reducing my excessive salt intake

This column appears monthly. Up next week: Annalee Newitz

IT'S that time of year, at least in the northern hemisphere, when people start to plan their summer holidays. I am in the market myself, hoping to take my sons to Mexico in July. We will fly, of course. I know I am a hypocrite for preaching a green lifestyle while participating in one of the most climate-damaging activities available. I always buy the carbon offset option, but have a lingering feeling I am being greenwashed. Now I have looked into it, I think that feeling is correct.

The last flight I took, I paid an extra $27.84 on a £1703.09 ($2137.21) ticket that took me 34,000 kilometres on a circuitous route from London to Tahiti and back. The certificate I got from the offsetting company says that I offset 1.69 "mt" of carbon. I am guessing that means metric tonnes rather than megatonnes. If so, it is nowhere near enough. According to an online calculator I later ran this through, I emitted more than 6 tonnes of carbon dioxide as a result of my flight. That alone busts my personal carbon budget, which should be no more than 2.5 tonnes a year.

I also have no idea whether that payment actually compensated for a portion of my emissions. What I assume is that the money – at least some of it – was invested in a voluntary carbon market, which is the only kind available. These allow individuals and companies to offset their emissions by investing money in nature-based solutions, such as planting forests, or in projects that prevent carbon being emitted in the first place. Voluntary carbon markets are the best thing we have at the moment, but are hugely flawed.

Leaving aside whether offsetting compensates for my emissions, there are transparency issues. I don't know what my $27.84 was invested in – the certificate says it was "distributed across our projects". These include tree planting, renewable energy projects and "avoided nature loss", which means preventing carbon emissions by not cutting down trees or changing natural habitat into farmland. The company's website tells me 90 per cent of my $27.84 went directly to one or more of these voluntary projects.

I have no reason to disbelieve the company's claim that they invested roughly $25 to support one or more of these laudable schemes. But according to Kaya Axelsson of the Oxford Net Zero project, there is a general problem in this area. "Carbon credits are generally invisible, it's hard for buyers to easily discern quality," she says. That is in part because the market is unregulated and lacks robust consumer protection.

"The offset market is a drop in the ocean of what is needed and a distraction from the true solution: decarbonisation"

One of the major grey areas is permanence. Carbon offsetting only works if it keeps carbon out of the atmosphere on the timescale that it lingers, which is thousands of years. Projects that involve planting trees can't promise this. They may work in the short term, but the carbon will eventually go back into the atmosphere.

The only offsetting worth its salt is that which permanently sequesters carbon in geological storage, says Myles Allen at the University of Oxford. But very few, if any, schemes offer this. In fact, he says, only 5 per cent offer carbon removal at all rather than avoided emissions, and they all invest in short-term solutions.

This opens the door to the second big problem: additionality. How do we know the offset wouldn't have happened anyway? The industry routinely indulges in a vice called double-counting, in which offsets are sold for projects that have already been announced and factored into somebody else's net-zero commitments. If that is the case, an investment is worthless.

The third big problem is scale. Right now, human activity emits 100 million tonnes of carbon a day, according to Injy Johnstone at the University of Oxford, an author of the world-leading Oxford Offsetting Principles. Offsetting removes just 5.5 per cent of that, she says, and the prospect for closing the gap is minimal.

All told, the offset market is a drop in the ocean of what is needed and a distraction from the true solution: decarbonisation. It also perpetuates our mass addiction to consumerism. Axelsson likens it to the medieval Catholic system of indulgences, where worried believers did good works to reduce the punishments they would endure in the afterlife.

I don't like to think of myself as a consumer of indulgences, but I have come to believe my offsetting is exactly that. Mexico may be the last long-haul flight I take, at least until offsetting is put on a more scientific and credible footing.

It's not too late to do that, but serious reform and oversight is needed. Offsetting can, when done well, play a vital role in achieving net zero, says Johnstone. "We urgently need climate mitigation, and offsetting strategies are one key lever we have to do so," she says. But when you click the button on an "offset" for your flights, be aware that you are probably being had. ▮

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SECRETS OF THE NEANDERTHALS/NETFLIX

New Scientist video
See Alison George get up close and personal with Shanidar Z at youtu.be/gf7P_NiqLOs

Ancient gaze

MEET Shanidar Z, one of the most important Neanderthal discoveries in a generation. Her remains, thought to date back 75,000 years, were fully unearthed five years ago in a re-excavation of the Shanidar cave (bottom centre) in the Kurdistan region of Iraq.

She appears to have been deliberately interred along with a cluster of nine other Neanderthal men, women and children, whose skeletons were uncovered from the 1950s onwards and transformed our understanding of Neanderthals. The remains revealed that these ancient hominins cared for the injured and the dead, and may even have put flowers in burial sites. So the recent discovery of Shanidar Z was especially exciting.

When the skeleton was found, her skull (top left) was crushed flat. It took more than a year to put the pieces back together in 3D form. This skull was then used by palaeo-artists Adrie and Alfons Kennis to create a model of what she might have looked like (top right). The twins, known for reconstructions of ancient hominins, are shown with the 3D print-out of Shanidar Z's skull (bottom left).

Her DNA didn't survive, so her genome couldn't be sequenced, but there is still lots to learn from Shanidar Z's remains. Chemical traces in tartar on her teeth are being analysed to reveal what her diet consisted of. Her front teeth were also worn down to stumps. "They were probably used like a third hand, to do things like processing hide," says Emma Pomeroy at the University of Cambridge, who is shown working on the skull (bottom right).

After so long buried, Shanidar Z is now in the limelight as part of a new documentary, *Secrets of the Neanderthals*, on Netflix.

Alison George

Editor's pick

Terraform a new world or shift biology to live there?

20 April, p 18

From Bernd-Juergen Fischer, Berlin, Germany

It is rather anthropocentric to say that to seek advanced alien life, we should search for clusters of planets that look remarkably similar, a sign of terraforming. Extraterrestrials that are sufficiently evolved to cross space and colonise other worlds might not need to terraform them. They are probably highly adaptable and can do the opposite: terraform themselves. That we can't colonise Venus, for example, isn't the fault of the planet, but our own biology. Others might not be so limited.

Soil could be the saviour in the carbon capture stakes

20 April, p 8

From Louise Quigley, Braintree, Massachusetts, US

It is a mistake to pursue unproven high-tech solutions to storing carbon when we already have a proven technology that could be quickly and widely implemented: regenerative agriculture. This uses established techniques to create a living soil that can sequester a great deal of carbon per hectare.

Conventionally farmed soil can be improved in three years simply by withholding chemicals and using compost and green manures as fertilisers. Something like half of Earth's habitable land surface is used for agriculture, so application of these techniques, plus switching from fossil fuels to renewable and nuclear energy, could possibly turn the tide on climate change, if we do it widely and promptly.

Vegans and veggies can still get their omega-3s

27 April, p 40

From Erik Foxcroft, St Albans, Hertfordshire, UK

In her article on omega fatty acids, Jasmin Fox-Skelly states that the most important thing to do to get more omega-3 in your diet is to eat more oily fish. Vegetarians, vegans and people who don't want to eat fish should note that the fish don't make the DHA and EPA omega-3s they contain themselves: this is done by marine algae, then passes up the food chain.

It is possible to bypass this and get the oils from the algae via food supplements. These are similar to fish-oil capsules, but are vegan.

Rapidly reversing eco-anxiety will be hard

6 April, p 36

Kevin Healey, Sydney, Australia

Eco-anxiety specialist Caroline Hickman suggests that "if we stopped oil extraction and shifted to renewables, eco-anxiety would almost disappear overnight". Even in the best-case scenario, the climate effects of these measures would take some time to be felt, and by then the focus will undoubtedly have shifted to other ecological concerns, perhaps biodiversity loss and the effects of microplastics. Sadly, the future looks bright for eco-anxiety.

Explanation of complexity couldn't have been clearer

20 April, p 40

From HildaRuth Beaumont, Brighton, UK

The J. Doyne Farmer interview on conceptualising the economy as a complex system with emergent behaviour was fascinating. As an ex-teacher, what I particularly enjoyed was the grass-zebra-lion analogy, comparing the interdependence of specialised entities in an ecosystem to those in the economy. Although an oversimplification, it was very easy to understand and was capable of extension by what-if questions. Simply brilliant.

Dark matter might be older than the universe

4 May, p 40

From Ian Napier, Adelaide, South Australia

Dark matter remains quite an enigma. If it exists, we have to confront a situation where the big bang created two separate types of matter – the normal matter we see today or its precursor (making up around 20 per cent of the total) and dark matter (about 80 per cent).

Alternatively, we may need to consider that space wasn't empty prior to the big bang and, in fact, already contained all of the dark matter that seems to be present now. The latter is quite attractive, since the concept of "empty" space is but a belief.

Vines can be fine, but perhaps not in all cases

30 March, p 44

From Geoff Waller, Auckland, New Zealand

I take no issue with the thermal advantages of vines growing on buildings. These plants may cause few problems with certain modern brick or tight-dressed stone walls, but they can grow into, and feed off, the lime cement mortar of older buildings. Likewise, the roots rapidly get behind wooden clapboard walls.

The world is awash with technological optimism

Letters, 20 April

From Sam Edge, Ringwood, Hampshire, UK

Nigel Tuersley's comments on the risks of technological optimism are too true. As well as the throwaway attitude he mentions of thinking we will be able to leave Earth, the argument from some quarters that we will find an engineering fix to climate change is dangerous and used to delay urgently required action.

Less may be more in the search for answers

23 March, p 32

From Lawrence Ryan, Wilsonville, Oregon, US

When I taught undergraduates the scientific method, parsimony was a key element. I find this lacking in suggestions that we may live in a simulation. Two scenarios (among perhaps more): our lives are the result of material evolution that gives us the consciousness and intelligence to one day program such a simulation, or another species has already materially evolved these traits to create the program that we live within.

The latter is possible, but seems an unnecessary complication, as the former is sufficient to explain our existence. And how much information would be required to simulate the lives, and inner lives, of more than 8 billion people? Will computer power continue to grow sufficiently to allow our simulators to generate us? Now, that is a philosophy student's PhD thesis: what is the information load of a human simulation?

Ockham and his razor are in a wild spin

13 April, p 8

From Alan Wells, Wellington, New Zealand

With all this talk of the quantum multiverse, many-worlds and now many-more-worlds, William of Ockham must be spinning in his grave. In multiple universes. ▮

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For the record

▮ **Thomas Metzinger's book, *The Elephant and the Blind*, has been made available as open access (27 April, p 28).**

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Of eggs and evolution

From large and shell-covered to tiny and jelly-like, the developmental story of eggs offers a way to rethink the story of life, discovers **Tom Leslie**

Book
Infinite Life
Jules Howard
Elliott & Thompson

WHAT do you think of when you picture an egg? Almost certainly something oval – most likely a hen's egg, at least at first. But eggs as a broader category exist in many forms and have been around almost since the dawn of multicellular life.

Yet, as science writer Jules Howard lays out at the start of *Infinite Life: A revolutionary story of eggs, evolution and life on Earth*, they rarely take centre stage in accounts of evolutionary history. In fact, the entire period between conception and birth barely gets a look in. Instead, the spotlight is fixed on tales of competition, predation and sexual selection, whose players are already off gallivanting around the world.

That won't do, says Howard. Taking us on a journey from 635 million years ago to the advent of *Homo sapiens*, he argues that eggs – whether large and shell-covered or minuscule and jelly-like – have been key to some of the most profound innovations in the history of life on Earth.

Among the many things that we fail to appreciate about eggs is their role in the move from water to land. Importance is usually placed on the development of robust limbs and on the capacity to breathe air. While both are clearly essential, so, too, is a tougher, hardier egg that can withstand exposure to the atmosphere without drying out, explains Howard.

This was evident during the Carboniferous Period some 350 million years ago, when insects and the lineage of vertebrates that would give rise to mammals and reptiles independently developed additional membranes around their eggs, allowing gases in and out while locking moisture inside.

The change empowered these animals to exploit new niches further away from rivers, ponds and swamps, resulting in an explosion of diversity. Without it, says Howard, all insects would be like silverfish – unable to live anywhere except where it is humid and damp – while all land vertebrates would be more closely tied to the spawning pool, much as amphibians are today.

"Among the many things we fail to appreciate about eggs is their role in the move from water to land"

The consequences of this shift are captured in his prose. For example, in order to leave its waxy egg, glued with "surgical precision" to the underside of a leaf, a young shield bug must pop open an "escape hatch" before clambering into the great beyond. The immensity of the project facing a baby vertebrate as it emerges from its egg is likened to leaving behind "a locked room, for single occupancy, inside which is a well-stocked kitchen, a comfortable bed, good insulation and a chemical toilet".

I did find myself a little disappointed, however, that Howard didn't go into more detail on the fossil evidence for landmark events in egg development. While brief mention is made of Alfred Romer, who discovered what was once thought to be the earliest amniotic egg – the kind developed by the ancestors of reptiles and mammals – more space could have been afforded to explaining how we know when this marvel evolved.

During later chapters, Howard's scope broadens significantly as he considers the development of the larval life stage in insects, the relative merits of the marsupial's pouch versus the placental mammal's uterus, and how parental habits in watching over eggs may have played a role in the rise of the dinosaurs.

While this departure from egg anatomy can jar, it starts to make sense when you realise that each development is made possible only because of the egg. For example, in the case of marsupials and placental mammals like humans, the umbilical cord is derived from and extends the concept of the allantois, one of the membranes in amniotic eggs that helps the embryo exchange gases and handle waste.

Overall, *Infinite Life* achieves its goal of putting the egg front and centre in the story of evolution. Though it sometimes lacks depth, it makes up for this with an excellently told story covering a broad range of evolutionary time. If you are anything like me, the areas where it is sparse will simply compel you to find out more – which makes it an excellent primer for new ways of thinking about the story of life on Earth.

An eastern Hermann's tortoise prepares to leave its egg for the world

EDWIN GIESBERS/NATUREPL.COM

They're out there...

For the best chance of finding alien life, we must tap into all human diversity, writes the scientist leading the hunt. **Abigail Beall** explores

Book

Alien Earths
Lisa Kaltenegger
Allen Lane (UK)
St. Martin's Press (US)

RICHARD BIZLEY/SCIENCE PHOTO LIBRARY

A PLANET where a year lasts just one week due to it whizzing around its star 70 times quicker than the fastest fighter jet. A scorched, Earth-sized world, with two suns, where rocks melt into lava, evaporate and fall as rain. Planets with surfaces covered in vast, deep oceans. Others where their sun never sets, unless you travel to the distant reaches of their cold side.

These are a handful of the weird and wonderful planets visited in *Alien Earths: Planet hunting in the cosmos* by Lisa Kaltenegger. There is nobody better suited to take us on that journey. An astrophysicist and astrobiologist at Cornell University in New York, where she heads the Carl Sagan Institute, Kaltenegger has been working on how to find life on alien planets since the 1990s, when exoplanet discovery truly started.

The book flits between memories from her career and chapters that explore the biggest questions about alien life, ranging from what we have learned about how life emerged on Earth to what the most unusual exoplanets are and how we can find them, plus, arguably the biggest question: how do we define life? It is clear Kaltenegger's knowledge is deep and expansive, but she has a lovely way of explaining difficult concepts by breaking them down and using descriptive language.

We go from learning about the strangest life forms on Earth – from nests that glow orange and flying squirrels that turn pink under UV light – to beautiful descriptions of what it might be like to be on an alien world.

The amazing differences we may find on other planets highlight the basic difficulty in defining life

"The blue hues of giant storms intertwined with light gray rivers of air cover most of the planet's visible surface, pushing against each other," she writes. "The merciless sun heats the winds to speeds higher than any on Earth." These insights into alien planets and what we have gleaned from studying them are peppered throughout her book. But it is about more than just exoplanets and the search for extraterrestrial life.

We go with Kaltenegger as she revisits important moments in her career, from the deployment of the James Webb Space Telescope to the first discovery of Earth-like planets in the habitable zone, a place where liquid water could exist on their surface. There are intimidating conferences – and the view from her office (once inhabited by Carl Sagan, the astronomer and science communicator popular in the 1970s and 80s). These personal insights offer a refreshing change of pace from the book's scientific content and they also provide important context for understanding Kaltenegger's career and appreciating all her accomplishments.

In one section that does this particularly well, Kaltenegger recounts times when she faced sexism in her career. She recalls when interviewers started probing into her personal life to gauge whether she had children or might do so soon, or when her PhD student overheard colleagues speculating that she had only been given a highly competitive position because of her gender. Her reaction is stoic and logical. "Find a group of people you trust and listen to their advice," she says.

Someone picking up this book expecting pure science might find these personal reflections jarring, but to me they are important to the story. And Kaltenegger is telling it from her own perspective.

She encourages others who might be discriminated against not to give up and asks those who do the discriminating to take a step back and look at their actions. "The very best chance for humankind to be successful in this quest [for alien life] is to have the broadest, the most diverse, spectrum of thinkers working together," she says. "People from all backgrounds, cultures, and genders are needed." ▮

New Scientist *recommends*

Madeleine Cuff
Reporter
London

I have just returned to work after the birth of my first baby, and have spent my commutes devouring **Child**, a podcast from BBC Radio 4. It travels from a sperm meeting the egg to the baby's first birthday.

India Rakusen hosts a fascinating dive into the science, history and culture of pregnancy, parenthood and early years development. Episodes meander from the prosaic – prenatal nutrition, for example – to the conceptual, like how perceptions of time shift for new parents.

BBC

This isn't just a series for those in the grip of early years parenting. Topics like fatherhood and childcare raise big questions about how society shapes, defines and values new life.

I also enjoyed the novel **Birnam Wood** by Eleanor Catton, which pits an anti-capitalist guerilla farming collective against an entrepreneur intent on acquiring billions of dollars of rare earth minerals, regardless of the environmental cost. A literary thriller, with a side order of dystopia – my kind of beach read.

The sci-fi column

Looking up Thomas Hart lives in 1990s small-town Essex, writing novels and local newspaper columns. Comet Hale-Bopp's approach is big news – and transformative for Hart – as we learn in the moving story *Enlightenment,* says **Emily Wilson**

Emily H. Wilson is a former editor of *New Scientist*. *Gilgamesh*, the second novel in her *Sumerians* trilogy, is out later this year. You can find her at emilyhwilson.com, or follow her on X at @emilyhwilson and on Instagram at @emilyhwilson1

PHIL BALL/SHUTTERSTOCK

Comet Hale-Bopp was visible with the naked eye as it passed Earth in 1997

SARAH PERRY is a writer most famous for *The Essex Serpent*, recently made into a high-end TV show on Apple TV+. Perry, being neither a sci-fi author nor a science writer, has until now given us no cause to include her on these pages. Her new novel, *Enlightenment*, however... the clue is in the title.

In this gorgeously written, witty and very moving novel, our hero Thomas Hart is a man of the arts, a novelist and a columnist at the *Essex Chronicle*. He is also a gay man who regularly attends a chapel in the small town in Essex where he lives, with a congregation that considers being gay a sin. He is close friends with the worshippers there, including a teenager called Grace who he has been looking out for since she was a baby. These chapel friends don't know Hart is gay, nor what he does when he takes trips to London.

Our story begins in 1997 when, at the age of 50, Hart is asked by the paper to write about astronomy. Comet Hale-Bopp is approaching and astronomy is having something of a moment.

And so our hero looks up at the sky and takes his first steps into science. Very quickly, he is transformed into a passionate amateur astronomer, and his new interest breeds new adventure. He begins to investigate a local mystery involving a 19th-century female astronomer. Through this investigation, he meets a man, James, at the local museum and

"The novel has a magical timelessness to it, perhaps because Hart is such a courteous, curious gentleman"

falls in love, although he can't be sure that James feels as he does. Meanwhile, Grace finds love of her own and the wheels of our story are set spinning. I won't say any more about the plot, except that it spans decades and Hale-Bopp isn't the only comet to feature.

The novel is clearly date-stamped as we progress through Hart's life, yet it has a magical timelessness to it, perhaps because he is such a curious, courteous gentleman who might have been at home in centuries past. Perhaps also because the chapel's worshippers might easily be denizens of a much older age, and because the mystery of the female astronomer feels as vibrant as the stories happening in the "now" of Britain in the 1990s and 2000s. The book involves emails and texts at times, but even these don't read so differently from the letters the astronomer sends to her mysterious friend, C, deepening the feeling that all this might have happened at any point in the past 200 years.

Very deliberately, the movements of the heavens are invoked time and time again as the story moves on. Planets, the moon and comets rise and fall around each other, and our characters also make their orbits, heaving into view and out again.

I have read elsewhere that Perry, who was brought up in a very strict Baptist church and is also a passionate amateur astronomer, was worried this novel might somehow dishonour God. For me, at least, the book didn't read as any sort of rejection of religion. Hart's columns in the newspaper (fictional, of course) punctuate the book most delightfully and they explore his feelings about science and religion very elegantly. At one point, he writes: "I've heard it said that at the first sip of the natural sciences you will become an atheist – then at the bottom of the glass, God will be waiting for you."

Enlightenment is a beautiful, compassionate and memorable book, one that will repay reading more than once. It has inspired me to go outside and look at the heavens more often. I may even take some binoculars! ▮

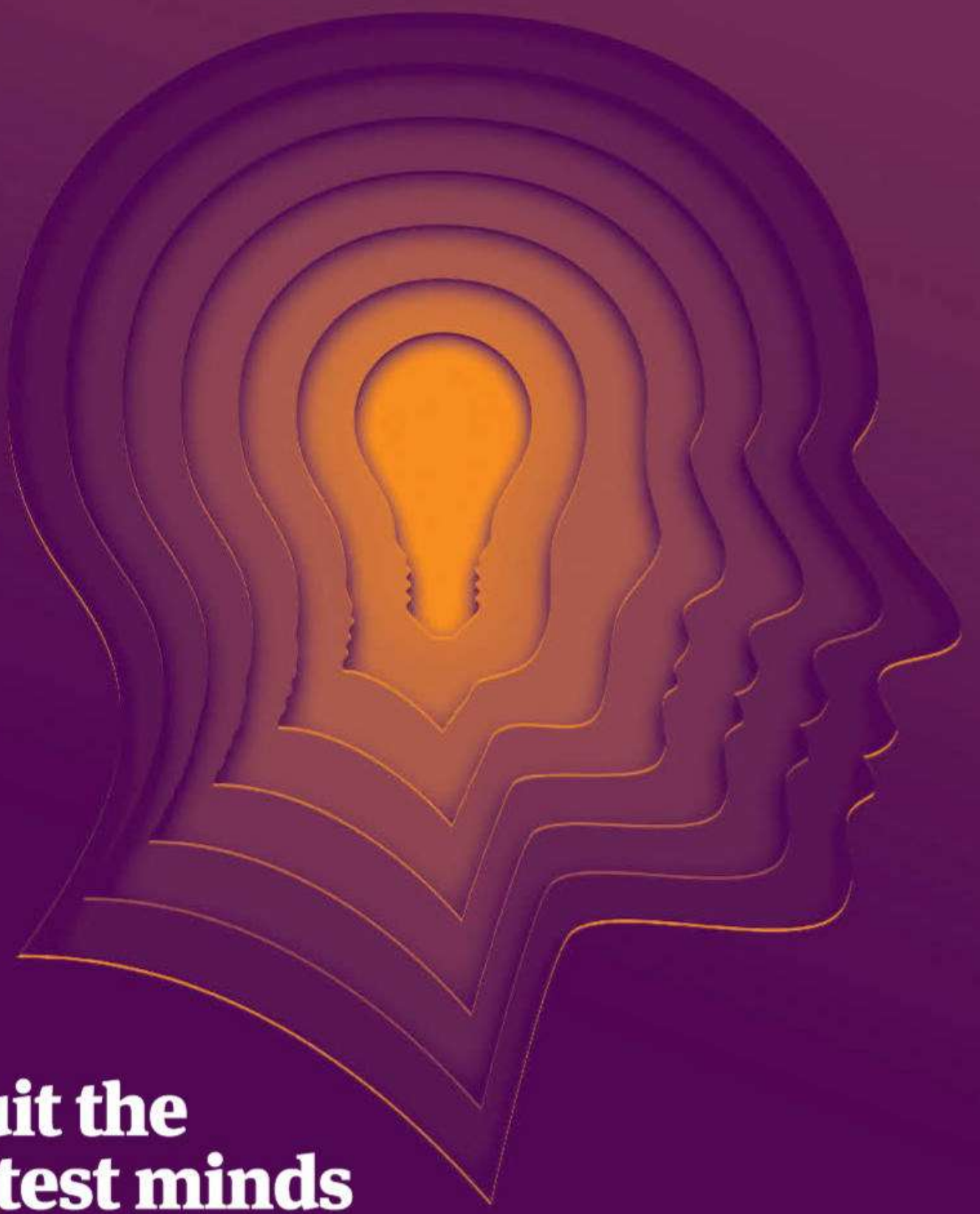
Book
Enlightenment
Sarah Perry
Jonathan Cape

Emily also recommends...

Book
Master and Commander
Patrick O'Brian
Harper Collins

Since we are straying rather far from our traditional fare this week, I will take this opportunity to strongly recommend O'Brian's great Aubrey-Maturin adventure series, which begins with Master and Commander. *How I love these books! One of the two main characters, Stephen Maturin, is a man of science, as well as a spy and a ship's doctor. All 20 of these novels are suffused by Maturin's love for the natural world and scientific research.*

Jobs
NewScientist



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They came by sea...

It is one of the greatest mysteries of ancient history: who were the Sea Peoples blamed for the destruction of a string of civilisations 3000 years ago? **Colin Barras** investigates

RAMESSES III was one of Egypt's great warrior pharaohs. A temple he built at Medinet Habu, near the Valley of the Kings, highlights why. On its walls, carvings tell the story of a coalition of fighters that swept across the eastern Mediterranean 3200 years ago, destroying cities, states and even whole empires. "No land could stand before their arms," this account tells us. Eventually, the invaders – known today as the Sea Peoples – attacked Egypt. But Ramesses III succeeded where others had failed and crushed them.

In the 200 years since hieroglyphics were first deciphered, allowing us to read Ramesses III's extraordinary story, evidence has come to light to corroborate it. We now know of numerous cities and palaces across the eastern Mediterranean that were destroyed around that time, with the Sea Peoples often implicated. So widespread was the devastation that, for one of the only times in history, several complex societies went into a steep decline from which they never recovered. Little wonder, then, that this so-called Late Bronze Age collapse has fascinated scholars for decades. So, too, has the identity of the mysterious sea-faring marauders.

Today, new genetic and archaeological evidence is giving us the firmest picture yet about what really went on at this dramatic time – and who, or what, was responsible. This shows that many of our ideas about the Sea Peoples and the collapse need completely rethinking. It also hints at a surprising idea: the end of civilisation might not always be as disastrous as we think.

Before the Sea Peoples arrived, life was good in the Late Bronze Age of the eastern Mediterranean – if you were an elite member of society, that is. During this period, between 1550 and 1200 BC, kings from Mycenaean Greece in the west of the region to the rulers of Babylonia in the east lived in opulent palaces, taking advantage of a thriving trade network to procure all the luxuries of the time, from gold and jewels to ivory and fine wines.

Collapse of civilisations

Then things fell apart. In Mycenaean Greece, where there were a handful of small kingdoms, the palaces were destroyed and the nature of society completely changed. "There was an end to fine craft production," says Guy Middleton at Newcastle University, UK. The Mycenaean tradition of writing ended too, with their script – Linear B – falling out of use.

The chaos wasn't confined to the Mycenaean world. Notably, the powerful, 450-year-old Hittite empire that controlled most of Anatolia (roughly corresponding to modern Turkey) fragmented. In fact, some researchers think that most cities along the Anatolian coast and down the eastern shores of the Mediterranean were destroyed. This included Ugarit, a city in what is now Syria – and here there seems to be clear evidence of what went wrong.

Several archives in cuneiform, another ancient writing system, have been unearthed during excavations at Ugarit, and some of the texts appear to be letters composed by Ugarit's king, Ammurapi, just before the city's downfall. In one, translated in 2016, the desperate ruler writes that "the enemy forces are stationed at Ra'šu [one of Ugarit's ports]".

In light of such evidence, it is easy to see why many researchers think Ugarit was sacked by a seafaring force – most probably the Sea Peoples described in engravings on Ramesses III's temple. These warriors were credited with incredible strength by the ancient Egyptians. "Not a single Egyptian foe has ever been assigned such powers... never has an enemy been described as the destroyer of empires," wrote Shirly Ben Dor Evian at the University of Haifa, Israel, in a 2018 study of ancient Egyptian texts. But who were these people?

Even today, the question lacks a definitive answer, but a handful of ancient clues are helping to build a clearer picture. A good starting point are the battle scenes carved on the temple. These show that one group of fighters in the Sea Peoples coalition wore horned helmets and carried long swords and round shields. This gear – reminiscent of the stereotypical idea of a Viking warrior – is unlike anything used by combatants in the eastern Mediterranean Bronze Age. But it had been seen in Egypt before. Similar equipment was carried by invaders who had assaulted Egypt a century earlier, and who were depicted on monuments left by the pharaoh in charge at that time, Ramesses II, who named the attackers as the Šardana.

For obvious linguistic reasons, researchers suspected that the Šardana hailed from Sardinia, suggesting some Sea Peoples had roots in this island off Italy or southern Italy more generally. But we can't be sure of the link, says Reinhard Jung at the Austrian Academy of Sciences. He points out that there are no Sardinian texts from that time, so we don't know if the locals used the name Šardana to describe themselves. The archaeological evidence is largely lacking too. "There was an unfortunate religious habit in southern Italy not to place armour in the tomb," says Jung, which means we don't know whether warriors from this region really did wear horned helmets. Swords from the area do, however, look like those carried by the Šardana as depicted on the Egyptian monuments.

There are other reasons to suspect that the Sea Peoples coalition included a southern Italian contingent. Many settlements in that area were attacked and destroyed in the final centuries of the Bronze Age, possibly by invaders from northern Italy. And if the ›

COKE NAVARRO

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southern Italian settlements were destroyed, perhaps their inhabitants were forced to flee. Jung says it would make sense for them to sail to a region they knew, either to raid the land or to search for new homes.

Significantly, in the past 20 years we have new evidence that the southern Italians traded with the eastern Mediterranean and so must have been familiar with the area. For example, we now know that a distinctive style of pottery that began appearing in Mycenaean Greece towards the end of the Bronze Age – known as handmade burnished ware – was southern Italian in origin. And in 2019, an analysis of ancient DNA showed that pig bones found at one Mycenaean palace had a genetic signature suggesting the animals came from Italy.

With evidence like this, a tentative explanation for the Late Bronze Age collapse emerges. The communities of southern Italy were uprooted towards the end of this period. They moved east and – either deliberately or inadvertently – destabilised the kingdoms of Mycenaean Greece (see map, below). As those so-called palace economies quickly descended into chaos, many Mycenaeans lost their homes too, swelling the ranks of the displaced. The coalition of migrants continued pushing along the coast in search of new homes, destroying cities and states in their path, before they met their match while attacking Egypt.

Ramesses III's temple seems to provide more support for this narrative of destructive migrants. The pharaoh named one of the groups in the Sea Peoples coalition as the Peleset. Today, many researchers identify the Peleset with the Philistines, who lived in a region – Philistia – now chiefly encompassing the Gaza Strip and parts of southern Israel.

Importantly, it has long been suspected that the Philistines were foreign invaders who took Philistia by force roughly 3200 years ago. Moreover, many researchers argue that the Philistines hailed from Greece, because some of their pottery looks Mycenaean. In 2019, genetic evidence seemed to confirm this link. An analysis of ancient DNA showed that four infants who lived in Philistia about 3100 years ago had a genetic signature linked to places in southern Europe such as Greece and Sardinia, indicating a wave of immigrants to the region.

For decades, however, there has been no good explanation for why such chaos and mass migration would have unfolded quite so dramatically. But here, too, recent research provides some clues. Several studies have concluded that the Mediterranean experienced a centuries-long megadrought at the end of the Bronze Age. The suggestion is that this triggered chronic food shortages and social unrest – priming the region for the collapse of civilisations.

But, for a growing number of researchers, this sounds more like a Hollywood plot than an account of real history. They argue that a more critical examination of the evidence suggests there was, in fact, no destructive wave of migrants sweeping across the Mediterranean

The Egyptian pharaoh Ramesses III defeats the Sea Peoples in this 19th-century illustration of carvings on his temple

and no centuries-long drought. In fact, some even doubt there was a Late Bronze Age collapse in the sense of a single region-wide disaster. "People turned this up to 11, and we have to take it back down to 3," says Jesse Millek at Leiden University in the Netherlands.

Re-examining the evidence

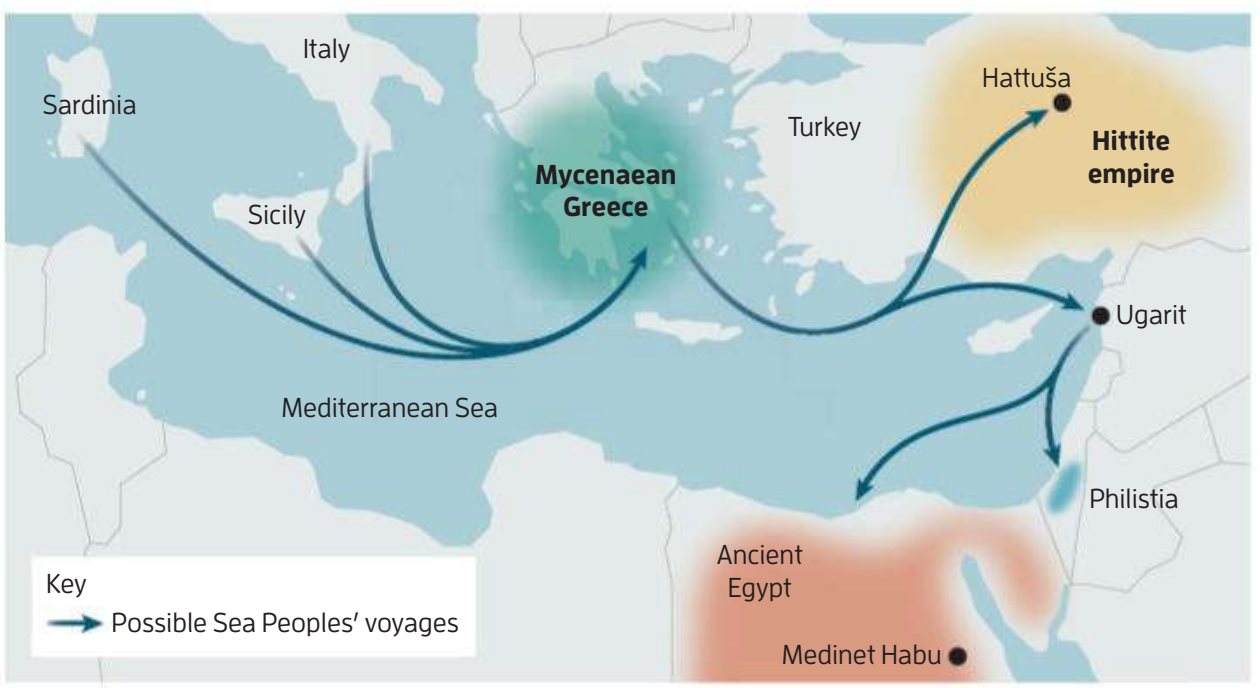
To begin with, Ramesses III's evidence about the nature of the Sea Peoples becomes more opaque under cross-examination. There is notorious ambiguity in ancient Egyptian texts, which makes them tricky to interpret. Ben Dor Evian's 2018 re-analysis suggests that the pharaoh actually meant the Sea Peoples were in fact employed by the Hittites, rather than destroying them. And a 2022 study made the case that the term Ramesses III used to describe the Sea Peoples chiefs suggests they were more likely to be leaders of bands of pirates than a formidable army.

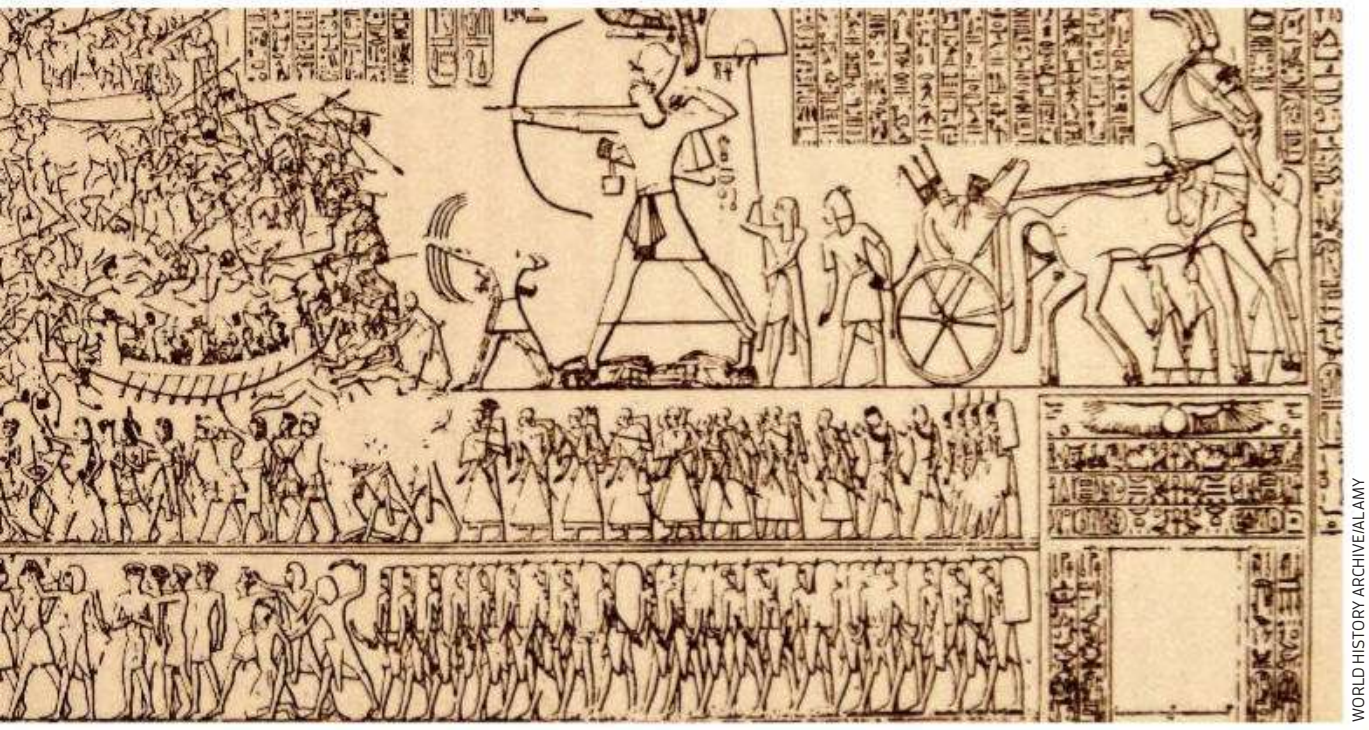
Even with these more nuanced interpretations it is never wise to build the foundations of history on words approved by a pharaoh. Doing so would be the equivalent of a future historian trying to understand the 21st century world solely by reading an account endorsed by Russia's president Vladimir Putin, says Sturt Manning at Cornell University in Ithaca, New York. "It would give you an odd view of events," he says.

Moreover, researchers have taken the accounts on Ramesses III's temple and hyped them up further. Some have argued that the Sea Peoples were responsible for the destruction of the Mycenaean kingdoms

Destruction of the Late Bronze Age

Around 3200 years ago, the Mycenaean and the Hittite civilisations both collapsed and the Egyptian empire was attacked. If the mysterious Sea Peoples were to blame, this is one potential route they took





WORLD HISTORY ARCHIVE/ALAMY

and dozens of cities – including Ugarit – in the eastern Mediterranean. But Ramesses III mentioned few of these places in the list of sites he says the Sea Peoples laid to waste.

Worse, many of them may not have been razed at all. Over the past few years, Millek has re-examined the field notes taken years ago as these places were excavated. At most of them – including those in Philistia that the Philistines supposedly took by force – the evidence for destruction is weak. At Ekron in Philistia, for instance, there is just a single burned storage building. As such, Millek doubts the Sea Peoples were really a cataclysmic force.

What, then, did happen? By abandoning the story that the Sea Peoples were responsible for a wave of destruction, alternative explanations become available. These include the idea that each kingdom and city collapsed independently because of specific local factors.

At first glance, that sounds implausible: so much chaos occurring simultaneously is surely no coincidence. But, in reality, the timeline of these events was probably more relaxed than that. "The destructions in Mycenaean Greece could have taken place over 15 or 20 years," says Helène Whittaker at the University of Gothenburg, Sweden. Across the region more broadly, it might have occurred over 50 years, says Manning – hardly evidence of a single, acute crisis.

Moreover, says Millek, for all we know there was a relatively high level of destruction throughout the 350 years of the Late Bronze Age, meaning it might not have been unusual for several cities to be under attack at any given time. Significantly, earlier this year researchers announced the discovery of a cuneiform tablet, unearthed in a Hittite city, which describes how "four cities, including the capital, Hattuša, are in disaster". It was written 200 years before the Late Bronze Age collapse.

New analyses of ancient climate are also making a region-wide crisis seem less likely. Although some studies appear to show that the Mediterranean experienced a centuries-long drought that began roughly 3200 years ago, Manning says this idea is "misleading". It is based in part on analyses of ancient pollen, which can reveal shifts in vegetation in response to changes in conditions. But most of these are low in resolution, with potentially decades separating data points, so they don't provide a full picture. "It's only when you have high-resolution sources, ideally annual data, that you see there's a great deal more complexity," says Manning.

"So much chaos, simultaneously, is surely no coincidence?"

Last year, he and his colleagues published a dataset capturing climatic conditions 3200 years ago near Hattuša. This came from analysing tree rings in ancient juniper logs to assess changes in rainfall from year to year. It showed there were plenty of "wet" years in Anatolia at the end of the Bronze Age.

The analysis did find evidence that Anatolia experienced a devastating, three-year drought between 1198 and 1196 BC, coinciding with the demise of the Hittite empire. But Manning and his colleagues concluded that this on its own probably doesn't explain that collapse. It is significant, they argue, that the Hittite royal family had splintered a few decades earlier. This meant that the drought hit while the empire was politically weak and less able to cope with problems such as food shortages.

It isn't just squabbling royals who can contribute to the fall of a civilisation. Middleton suspects that the general population, too, may sometimes play a part. For example, he says that when the Mycenaean palace states collapsed, many of the non-palatial rural communities of Greece continued apparently unaffected.

We don't know why, but one possibility – first suggested by Jung – is that it was the general population, rather than invading Sea Peoples, who destroyed the palaces. The idea is that they did so because the ruling elites had become too oppressive. "It might be that most people were glad to be rid of the palaces," says Whittaker.

This take on the Late Bronze Age collapse is arguably the most radical of all. We might like to imagine that a society capable of producing opulent architecture and written records is fundamentally better than a society lacking these features. As such, it is tempting to interpret the disappearance of sophisticated societies as evidence of an unexpected and unwanted catastrophe. But we forget there is an alternative, says Millek: that people may choose to stop building palaces and keep written records because they want a more egalitarian and uncomplicated society.

"Even today, many people say they would love to give up the trappings of modern life and go back to something simpler," says Millek. It is conceivable that some of the Bronze Age inhabitants of the eastern Mediterranean, including the Sea Peoples, felt the same way.

We still have plenty to learn about the dramatic events at the end of the Bronze Age. But as the evidence continues to accumulate, we may finally be able to acquit the Sea Peoples. It is possible they have been framed for "crimes" that may never have happened. ▮

Colin Barras is a science writer based in Ann Arbor, Michigan

Everyday toxins

"Forever chemicals" are finally being recognised as a danger to our health. But given they are woven deeply into our lives, can we ever be free of them? **Graham Lawton** investigates

IN 1938, chemist Roy J. Plunkett stumbled across a substance that would change the world forever. He was experimenting with refrigerant gases when he noticed that one compound had transformed into a white, waxy solid. It had extraordinary properties, being impervious to heat and chemical degradation and also extremely slippery.

Today, we know this chemical as Teflon, and produce more than 200,000 tonnes of the stuff every year. It is used in everything from non-stick frying pans to medical catheters. Though undoubtedly useful, Teflon was also the first of a group called perfluoroalkyl and polyfluoroalkyl substances (PFAS), better known as forever chemicals.

Almost as soon as Teflon was invented, concerns were raised about its potential impacts on the environment and our bodies (it is worth noting, though, that these days, using non-stick cookware is probably safe as the pans are heat-treated and don't release any nasties unless they are left on a high heat for a long time). Today, the world is finally getting to grips with just how dangerous forever chemicals can be to our health – and dealing with the problem head on. In January, the US Environmental Protection Agency (EPA) added nine forever chemicals to its list of hazardous constituents. And last month, the US imposed its first ever limits on levels of PFAS in drinking water, in a belated bid to reduce exposure to these ubiquitous chemicals. But what risks do they actually pose and what should we be doing to remove them from our lives? Researchers face a huge challenge in finding the answers, but are starting to make real headway.

PFAS are a diverse group of about 16,000 artificial chemicals used in a vast array of products. What they all have in common are fluorine atoms attached to carbon atoms. To qualify as one of the PFAS, a molecule must contain at least one "fully fluorinated" methyl or methylene group – a carbon atom with all its available bonds occupied by a fluorine.

The name "forever chemicals" is derived from the fact that they are incredibly stable, immensely heat tolerant, resistant to chemical degradation and also thoroughly repellent to water and oils. This combination of properties makes them useful in all sorts of applications, from non-stick cookware to outdoor clothing, stain-resistant furniture and carpets, food packaging, personal care products, paints, varnishes and firefighting foams.

But it also means that when they inevitably leak into the wild, they hang around for a long, long time – hundreds or even thousands of years, according to Zhanyun Wang at ETH Zurich in Switzerland. PFAS pollution has been found extensively in surface water and groundwater, soils and outdoor air, and has adverse effects on wildlife – it can cause suppressed immunity and reproductive issues in some animals, even at tiny concentrations.

These chemicals are also found in sewage, house dust, indoor air and drinking water. A study last year found that PFAS are in almost half of all tap water in the US. Unsurprisingly, they are also present in the human body. "An estimated 98 per cent of the US population have detectable concentrations of PFAS in their blood," says Carsten Prasse at Johns Hopkins University in Maryland. Not only do we drink them and inhale them, we also eat them in food that has been wrapped in PFAS-containing packaging, grown in PFAS-contaminated soil or caught in PFAS-contaminated water. They are eventually excreted in urine, but only slowly: in the human body, they take between a few months to five years to halve in concentration. Being so ubiquitous, rates of excretion can't keep up with rates of acquisition, so the older we get, the higher our PFAS load tends to be.

"An estimated 98 per cent of the US population have detectable concentrations of forever chemicals in their blood"

Disrupted metabolism

Being so stable and inert, the prevailing view was that these chemicals couldn't do much harm. That is no longer the case, says Birgit Geueke at the Food Packaging Forum in Zurich, a non-profit organisation governed by independent scientists. While human enzymes can't degrade them, PFAS can interact with biological systems by binding to cell receptors and other proteins and hence disrupt metabolism, she says, and there is ample data that certain PFAS are linked to cancer, immune dysfunction, kidney disease and more. "There's increasing evidence that there are toxic effects on a variety of levels," says Prasse.

PFAS are already regulated to a degree. Two of the ones about which the most is known – perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) – have been included in the Stockholm Convention on Persistent Organic Pollutants, which severely restricts their use. Others are being considered for inclusion, says Denis O'Carroll at the University of New South Wales in Sydney. Many countries have limits on the amount of PFAS allowable in food and drinking water.

But these measures are akin to shutting the stable door after the horse has bolted. In 2022, Ian Cousins at Stockholm University in Sweden and his colleagues found that levels of PFOS, PFOA and two other PFAS ›

greatly exceed advised limits in rainwater, surface waters and soils globally, and that this probably applies to many other PFAS too.

More recent research by O'Carroll found that a "substantial fraction" of source waters around the world exceed limits for PFAS in drinking water. That doesn't necessarily translate into unsafe drinking water, as many water treatment plants remove some PFAS. But O'Carroll points out that drinking water standards usually cover only a fraction of the 16,000 PFAS that are out there. Canada, for example, has one of the strictest drinking-water limits in the world – no more than 30 nanograms of all PFAS combined per litre – but only monitors 18 of these chemicals.

As a result, the US government recently announced more than $1 billion of funding towards addressing contaminants like PFAS in drinking and waste water. Two powerful US agencies are also stepping up their efforts to phase out PFAS and the EU is attempting to ban them outright.

One major mover and shaker is the EPA, which recently put restrictions on PFAS levels in drinking water after studies showed that no level of exposure to PFOS and PFOA is safe. It has also added nine PFAS to its list of hazardous constituents, the first step on a potentially torturous path to designate them as hazardous waste and hence strictly regulate their manufacture, use and disposal. "It appears the EPA is moving more aggressively to get PFAS out of our environment," says Greg Scoblete, at Verisk, a New Jersey-based company that advises its clients on emerging risks.

To be listed as a hazardous constituent, scientific studies must show that the chemical is toxic, cancer-causing, leads to changes in DNA or causes developmental abnormalities in humans or other animals. "In the case of PFAS, unfortunately, several of these criteria are met," says Prasse.

The question of what these chemicals actually do to our health is complicated. For ethical reasons, you can't expose a certain population to PFAS and others to a placebo. Instead, EPA scientists assessed the peer-reviewed literature on PFAS, including data from human epidemiology and animal studies, which together attempt to draw connections between exposure to PFAS and health problems – for example, by measuring vaccine responses in children versus the levels of certain PFAS in their blood.

Among the nine chemicals that the EPA decided to take action against was PFOA, which was widely used for decades in furniture, clothing and food packaging before its use was restricted globally in 2019 under the Stockholm Convention. The EPA concluded that humans regularly exposed to it are at greater risk of high cholesterol, liver damage, thyroid disorders, testicular and kidney cancers, pre-eclampsia, pregnancy-induced hypertension and low birth weight. They also experience a weaker response to several vaccinations. Studies on monkeys, rats and mice found similar problems, plus kidney toxicity, liver and pancreatic cancer and congenital conditions. The EPA published similarly detailed reviews of eight other PFAS.

WESTEND61 GMBH/ALAMY

Filtering water can lower your exposure to forever chemicals

"I think the step that the EPA is taking is in the right direction," says Prasse. "But I think it is important to consider that this can only be the tip of the iceberg, and that there's much more work needed to deal with this issue."

For instance, the big question on everyone's

How to avoid forever chemicals

Human exposure to perfluoroalkyl and polyfluoroalkyl substances (PFAS), also known as forever chemicals, which have been linked to numerous health problems, comes through many routes (see main story). Some are unavoidable if you wear clothes, have furniture or carpets or use consumer household products. But others can be swerved.

Food is a major source of exposure. The two things to be most wary of are greaseproof fast-food packaging – paper wrappers, pizza boxes, cardboard cartons – and bags of microwaveable popcorn, says Birgit Geueke at the Food Packaging Forum in Zurich, Switzerland.

Nowadays, the use of non-stick cookware is likely to pose no risk because it is heat-treated in the factory and so doesn't release any PFAS unless left on a high heat for extended periods, says Geueke.

Tap water is another important but mitigable source. Carsten Prasse at Johns Hopkins University in Maryland recommends using certified filters on taps or in water jugs.

Bottled water isn't necessarily the answer, says Denis O'Carroll at the University of New South Wales in Sydney. "It doesn't mean that they've done anything differently than what comes out of the tap."

There is no guarantee that these lifestyle changes will significantly reduce PFAS exposure. "I don't think we know enough to really say which exposure pathway is the most problematic one. I would say at this point all exposures are concerning," says Prasse.

There is, however, hope that PFAS can be scrubbed from the human body. A recent clinical trial found that administrating the cholesterol-lowering drug cholestyramine to people living in a PFAS hotspot near a firefighting school in Denmark reduced levels of these chemicals in their bloodstream by 60 per cent. Cholestyramine works by binding to cholesterol-rich bile acids in the gut and preventing them from being absorbed. PFAS are excreted in bile acids, but are mostly reabsorbed before being expelled in faeces – it appears that cholestyramine significantly increases the efficiency of PFAS excretion by this route. The results are "groundbreaking", according to the study authors.

lips is what level of exposure leads to what harms – a question that is challenging to answer. It is very hard to say what levels of PFAS are safe, says Prasse. "I would say we want to have as low levels as possible."

Another agency on the warpath is the US Food and Drug Administration (FDA). In February, it announced that greaseproof food packaging containing certain PFAS was no longer on sale in the US after the completion of a voluntary phase-out.

Food for thought

Food packaging is a significant source of PFAS in the human body. Earlier this year, Geueke and her colleagues found 68 different PFAS in food packaging materials, mostly added to paper, plastic and coated metal as barriers against moisture and grease. It is already well-established that PFAS migrate out of packaging into food and hence into the body, says Geueke.

Inevitably, PFAS manufacturers are pushing back. In 2023, five European nations submitted a proposal to the European Chemicals Agency to restrict around 10,000 PFAS in the EU and affiliated countries. In response, 13 PFAS producers are mounting a €20-million-a-year lobbying campaign to water down the proposals, according to research by the non-profit Corporate Europe Observatory group in Brussels, Belgium.

There are ways to replace PFAS with other chemicals, but whether they are safer is an open question. For instance, one option is to create similar compounds that use chlorine atoms in place of some of the fluorines, but according to Emiliano Panieri at Sapienza University of Rome in Italy, we don't really understand their impacts either. Attempts to replace PFAS could lead to cases of "regrettable substitution" where one toxic chemical is superseded by something worse, says Scoblete.

Replacement won't solve the problem of legacy PFAS already in the environment either. There are measures that we can take to reduce our exposure (see "How to avoid forever chemicals", left), but to solve the problem for good, PFAS need to be detected, removed and, if possible, destroyed.

Detection of PFAS in environmental samples is improving. The current gold standard method concentrates water samples and then applies gas chromatography and mass spectrometry to identify 18 PFAS at parts-per-trillion levels. The method is "elegant and ultra-sensitive", according to Yu Lei at the University of Connecticut, but is also expensive, time consuming, only applicable to water samples and restricted to the lab. "There is a strong demand for rapid, accessible, low-cost PFAS detection methods," says Lei. There has been a recent surge in techniques that tick those boxes and that can also test biological samples including blood, milk, meat and eggs, he says. Such research "paves the way towards a healthier future for humanity", says Lei.

ROO LEWIS/GETTY IMAGES

Several forever chemicals are found in food packaging

PFAS can also be removed. They can be filtered or adsorbed out of water and washed from soil, says Tanmoy Roy Tusher at Marquette University in Wisconsin. The problem is, these methods are also expensive and energy intensive. Cleaning up PFAS in drinking water in the US alone would cost trillions of dollars and create a huge carbon footprint, according to Wang. Thankfully, innovation is afoot. Bioremediation – using living organisms to remove PFAS from the wild – looks promising, according to Maria Greger at Stockholm University. She and her university colleague Tommy Landberg have shown that aquatic plants can absorb the chemicals from highly contaminated lakes and rapidly reduce their levels in the water.

> "New ways of detecting forever chemicals pave the way for a healthier future for humanity"

The plants can then be harvested.

But then what? Dealing with PFAS once they have been collected is another slippery issue. Incineration can destroy them, but is risky as it creates more unknown PFAS and may release them into the environment. Putting them in landfill risks them leaching out all over again.

But various new treatment methods are in the pipeline. Last year, for example, the US military began testing a method to destroy PFAS with superheated water. Nevertheless, most methods require a lot of energy and may produce toxic by-products, says Brian Chaplin at the University of Illinois Chicago.

Bioremediation may again be our answer. Greger's experiments with aquatic plants show that some are able to partially degrade PFAS using a process called enzyme-catalysed oxidative humification, though they don't break the stubborn carbon-fluorine bond. Some bacterial enzymes, however, can. At the University of Minnesota, Lawrence Wackett is working on genetically engineering these enzymes into defluorination systems, and artificially evolving them to be more efficient. "PFAS are not forever," says Wackett.

Until that proves true, though, we are going to have to live with the legacy of that serendipitous, slippery discovery in 1938. And so will future generations. "It's doubtful we'd be able to remove all PFAS," says O'Carroll. "It's pervasive." ▮

Graham Lawton is a staff writer at *New Scientist*

RENAUD VIGOURT

Race against resistance

We are tantalisingly close to a long-sought room-temperature superconductor. Can we take the final step, asks **Jon Cartwright**

IT WOULD be unfair to call it a philosopher's stone, yet there is something beguiling about the search for a room-temperature superconductor. This material would be able to transmit electricity perfectly, without any resistance. It could pick up renewable energy where it is abundant and deliver it efficiently to faraway cities, going a long way towards solving the climate crisis.

No wonder, then, that when not one, but two such materials were supposedly discovered last year, the physics world went into a frenzy. In March 2023, researchers reported a material known as "red matter" that could purportedly do the business at 21°C (70°F), albeit only at incredible pressures. A matter of weeks later, news broke of another substance called LK-99 that apparently worked at both room temperature and ambient pressure. Alas, all that glitters is not gold – both claims have now been widely dismissed.

But the fuss over those studies obscures a more subtle and interesting truth: broader research in pursuit of a practical superconductor is racing forwards and there is a sense that, finally, the search is turning a corner. In the past few years, there have been more experimental breakthroughs than you can shake a stick at, while theorists are honing a wealth of methods to predict the composition of new superconducting materials from scratch. "Folks my age can remember when it was absolutely certain: there will never be a room-temperature superconductor," says J. C. Séamus Davis, a physicist at the University of Oxford. "Only now we're realising how wrong we were."

It was back in 1911 that physicist Heike Kamerlingh Onnes discovered that at -270°C – just 3°C above absolute zero, the coldest possible temperature – the electrical resistance of mercury suddenly vanishes. No one expected this behaviour. All the top physicists of the day, including Albert Einstein, had a go at explaining it. But it wasn't until nearly 50 years later that a trio of physicists – John Bardeen, Leon Cooper and John Robert Schrieffer – cracked the puzzle. BCS theory, which bears their initials, is now regarded as a pinnacle of 20th-century science: beautiful in its simplicity, formidable in its predictive power.

To get your head around the idea, imagine zooming into the innards of a superconducting material, where negatively charged electrons create an electric current by moving through a lattice of positively charged atomic nuclei. As an electron moves, it attracts those nearby nuclei, setting them off in ripples of positive charge in its wake. This attracts another electron, dragging it behind the first, as if it were on a leash. These paired electrons – known as a Cooper pair – are then immune to the vibrations in the lattice of atoms that make up the material, which usually cause electrical resistance.

Many paths to glory

Unless, that is, the lattice is vibrating so strongly that it has enough energy to snap the Cooper pair's leash. In physics, more heat equals more vibrations, which explains why, according to BCS theory, superconductivity generally occurs at very low temperatures. Like any good hypothesis, BCS also made a prediction. It suggested that materials in which the lattice atoms were relatively light would superconduct at higher temperatures. Being lighter, these atoms would ripple more easily, creating a more robust leash between the paired electrons.

The theory explained all the superconductors then known, metals such as lead, niobium and tin, as well as the original mercury. For all of these, the point at which superconduction began – ›

the so-called critical temperature – was within a few degrees of absolute zero.

Then came 1986, and the surprise discovery by J. Georg Bednorz and K. Alex Müller at the IBM Zurich Research Laboratory in Switzerland of superconductivity in a copper oxide-based material, or cuprate, at a relatively balmy -238°C. Within a few years, other groups found similar materials that worked at even higher temperatures, up to -180°C. This was quite a shock. Not only were these materials regarded as insulators that don't usually conduct electricity at all, but they were utterly failed by BCS theory and its insistence that only materials made of very light atoms could superconduct at higher temperatures. Copper and oxygen didn't fit the bill. These cuprates became known as "unconventional" superconductors because they defied the BCS orthodoxy.

The materials kept getting better, though only up to a point. Today, the best unconventional superconductors operate at about -140°C. Still, that is good enough for some applications. They are used to make extremely strong magnets, for example, such as those found in MRI machines. We cool them to frigid temperatures using liquid nitrogen.

But what everyone really longed for was a superconductor that could be used anywhere, a technological panacea that would, among other things, revolutionise electricity networks. To get towards that, we needed a way to go beyond mere theory and test what the electrons inside unconventional superconductors are doing.

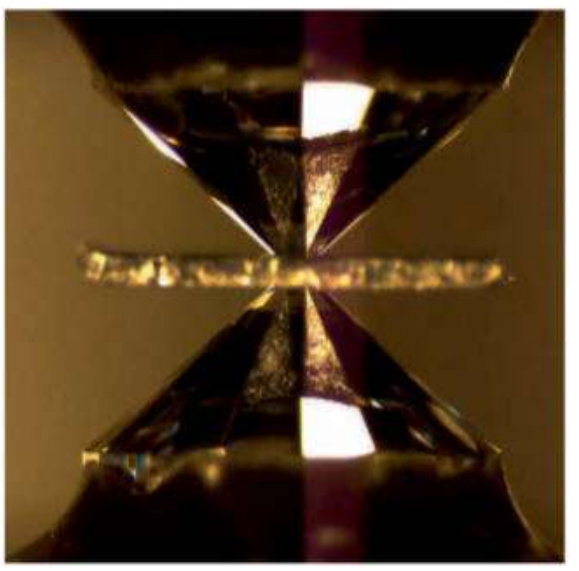
Davis and his colleagues managed exactly this in work published in 2022 that used a scanning tunnelling microscope, an instrument in which a metal needle scans the surface of a sample, with electrons hopping from it to the material being examined. They analysed one particular cuprate superconductor using two slightly different needles, one of which was itself superconducting. This allowed the researchers to obtain maps of the Cooper pairs. "It only took me just slightly less than 30 years," jokes Davis. "Nobody had ever visualised Cooper pairs before, by any technique whatsoever."

The team saw that the Cooper pairs were most numerous where hopping between the material and the needles was easiest. This, according to Davis, is strong evidence in support of a particular hypothesis of unconventional superconductivity put forward by the late Nobel laureate Philip Anderson. He said that electrons pair up in cuprates not by moving continuously, as in BCS theory, but in such a way that they correlate a quantum mechanical property called spin – one electron spins down, the next up, and so on.

"We went from one family of room-temperature superconductors to four"

The experiment will have to be repeated on a wide array of unconventional superconductors before Anderson's hypothesis is fully accepted. If it is, researchers can then confidently use the idea to predict the structures of new, better superconductors. That won't be easy though – Anderson's idea involves much more complicated interactions between the electrons than BCS theory and the simulations are incredibly onerous for even the best supercomputers.

Then again, maybe we don't need to bother with predictions from first principles at all. This is the hope offered by artificial intelligence, which is increasingly seen as a way to find better superconducting substances based on trends in existing experimental data.



STEVE JACOBSEN/SERC/CARLETON COLLEGE

Diamond anvils create the extreme pressures needed by some superconductors

Last year, a team led by Christopher Stiles at Johns Hopkins University in Maryland trained an AI algorithm using SuperCon, a database of the compositions of more than 16,000 known superconductors and the temperatures at which they start to work. In its initial computation, the AI predicted dozens of possible superconducting materials. The researchers already knew from the literature that some of these weren't really superconductors, so they put those predictions aside and made a handful of the other compounds suggested.

These were nothing special either, so the team fed all the negative data back into the algorithm and reran it. Still nothing.

The researchers repeated this process and by the fourth iteration, the AI spat out what they wanted: predictions for six superconductors, five of which were already known to be genuine (though not included in the original training data). Tentatively, they synthesised the other one, an untested alloy of the metals zirconium, indium and nickel. Lo and behold, when they cooled it below -264°C, it became a superconductor. Not warm enough to rock anyone's world, but proof of AI's potential.

Stiles doesn't know the mechanism by which the zirconium alloy works, and neither does the algorithm. It doesn't have to: like all AIs, its prediction boils down to statistical analysis. And it can only get better. "With this approach, the more data you feed in, the more predictive it gets," says Stiles. "Unlike me – the more data I feed on, the more I forget the earlier data."

Or perhaps we go back to BCS superconductors. For decades, that didn't seem promising because none operated much above absolute zero. But they did at least have a clear rule that pointed the way to higher-temperature operation: use lighter atoms. Indeed, the best performing superconductor of all may well be a fabled metallic form of the lightest element, hydrogen, which scientists have been trying and failing to synthesise for nigh-on 90 years. The next-best contenders could be the superconducting hydrides, alloys that contain as much hydrogen as possible – and it is these that have suddenly set the field alight.

Their rise began in 2015 when, on the basis of a promising prediction a year earlier, a team at the Max Planck Institute for Chemistry in Mainz, Germany, experimented with hydrogen sulphide. Subjecting the sample to pressures of 90 gigapascals, roughly a million times atmospheric pressure, the researchers found that it began superconducting at -83°C,

ROKAS TENYS/ALAMY

The supposed superconductor LK-99 has proved controversial

nearly 60°C warmer than the best cuprate. Other results swiftly piled in. Lanthanum superhydride, an alloy that contains 10 hydrogen atoms for every lanthanum one, has proved especially intriguing. By 2018, it was exhibiting signs of high-pressure superconductivity at -23°C. A year later, it was made to work at -13°C (9°F).

With things inching so close to room temperature, superconductivity research is becoming more competitive than ever. Perhaps that goes some way to explaining the furore over red matter and LK-99. The red matter paper has now been retracted at the request of some of its co-authors, who, among other issues, cited inaccuracies in the data. Meanwhile, repeated attempts to replicate the LK-99 experiments have failed. Scientists complain that they no longer know what to trust, and at present there is no consensus on what the highest temperature at which a superconductor works is, or in what material.

Arguably, that is irrelevant. All the superconducting hydrides investigated experimentally only work at high pressures, up to around 300 gigapascals, more or less the squeeze you would find at the centre of Earth. Achieving that requires a tiny sample and a diamond anvil press – like a thumbscrew, but with a pair of opposing diamonds to inflict the torturous force. Clearly, even if a high-pressure hydride does pass the room-temperature milestone, practical applications will be few.

Stalemate, then? Theorists widely agree that simple hydrides involving hydrogen and another element can't superconduct much beyond room temperature without being subjected to very high pressures. Equally, the original non-BCS superconductors, cuprates, are at something of a dead end too: progress plateaued in the mid-1990s. "It's tantalising," says Chris Pickard, a theorist at the University of Cambridge. "You see these nice curves of recorded critical temperatures go shooting up, but then they top out."

Many paths to glory

However, there are other avenues to explore. In 2019, a team at Stanford University in California discovered that materials similar to cuprates, but with nickel atoms substituting for copper, can also act as unconventional superconductors. At present, the maximum critical temperatures for these "nickelates" is around -193°C at ambient pressure, placing them well behind the pack. Yet this finding opens up a whole new set of materials for physicists to play with and optimise.

On top of that, we discovered another family of superconductors based on iron back in 2006, though the best they can manage so far – again, at standard atmospheric pressure – is around -217°C. But the point is that this expands the space in which we can experiment. "We went from one family of high-temperature superconductors to four," says Sven Friedemann at the University of Bristol, UK. "This demonstrates that multiple routes can lead to room-temperature superconductivity, and makes me very optimistic that room-temperature superconductivity is possible at ambient pressure."

Much hope now centres on the hydrides – but more complex ones, involving two elements in addition to hydrogen, rather than just one. Calculations suggest that the extra elements can help stabilise the atomic structures, rendering high pressures unnecessary. Earlier this year, an international group conducted a theoretical sweep of more than a million such hydrides and found that a subset that contain magnesium ought to superconduct at up to roughly -170°C at ambient pressure. At the same time, another international group of researchers, including Pickard, corroborated the result and also identified a particular magnesium-iridium hydride that should superconduct at an impressive -113°C. "If we're right, we've beaten the cuprates at ambient pressure," says Pickard.

As he admits, these studies can be taken both ways. The good news is that higher-temperature superconductivity is possible without high pressures. The bad news is that the extensive search still didn't turn up any room-temperature candidates. "It's good," says Pickard, "but not good enough."

Yet, as always in superconductivity research, surprises may await. At a meeting of the American Physical Society in March, Adam Denchfield at the University of Illinois Chicago presented the results of a new way of searching for promising hydrides. Rather than trying to work out how to reduce the pressures necessary to stabilise known superconducting hydrides, he and his colleagues do the opposite: start with those known to be stable at ambient pressures and see how they can be altered for high-temperature superconductivity. They found that a particular yttrium hydride with a scattering of lithium should, with some tweaking of the lithium content, superconduct at -53°C.

Still not room temperature, you might think. But there are error bars on that number and "they go both ways", Denchfield said at the meeting. He pointed out that the same theoretical prediction for lanthanum superhydride gave a critical temperature 60°C cooler than its measured value. Might -53°C be a similar underestimate for yttrium hydride? If so, room temperature suddenly isn't so far off, after all. ▮

Jon Cartwright is a freelance journalist based in Bristol, UK

The back pages

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Academic sleuthing and micro black hole batteries p48

Twisteddoodles for *New Scientist*
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The science of baking

Peak performance

Egg whites are key to so many bakes. Here are some simple tricks to guarantee yours form perfect peaks, says **Catherine de Lange**

Catherine de Lange is the editor of *New Scientist* and an avid baker

What you need

2 egg whites at room temperature
125 g (½ cup) caster sugar
225 g (2 cups) ground almonds
1 tbsp cinnamon
A few tablespoons of icing sugar

LAST week was the Jewish festival of Passover, when it is forbidden to eat any leavened products. That means all raising agents, as well as flour, are off-limits. Even so, there are dozens of traditional Passover cakes and biscuits, and mastering the techniques behind them can help you with all sorts of other bakes too. My go-to is the humble cinnamon ball, a sweet, soft biscuit with a crisp outer shell.

In general, the key to achieving airiness in your bake without raising agents will come down to using egg whites. These essentially consist of proteins and water, and as you whisk them, the curled-up proteins unravel and stretch out. These strands can bond with each other, trapping bubbles of air around the water, which allows the egg whites to expand to up to eight times their volume.

Unfortunately, egg whites are notoriously tricky to handle. Over-whisk, and these structures break down, leaving you with a grainy pile of watery egg. And there are times when, however much you whisk, the magic transformation from yellow gloop to white mousse never happens. But there are a few simple ways to (almost) guarantee yourself glossy peaks.

The first is to use a clean bowl. Any greasy residue will bind to the proteins, stopping them bonding with each other. The simplest way to avoid this is to run the cut side of half a lemon over your bowl. The acid lifts any residual grease. Using eggs at room temperature also helps the structures form.

Next, keep a close eye on your egg. As you whisk, you will go through three phases – soft peaks that melt away when you remove the whisk, firm peaks that hold their shape and then stiff peaks, which hold their shape both in the bowl and on the whisk.

OLGA MAZYARKINA/GETTY IMAGES

Resist the urge to keep going beyond this point. The foam is fragile, and if you take it too far, the bonds between the protein strands will begin to break again, causing the structure to collapse and the water to leak out. This will also happen if you leave the foam to stand in the bowl for too long.

Accepted wisdom has it that a copper bowl can boost your chances of perfect peaks. To test this, Harold McGee and his colleagues got whisking back in 1984. They found it took longer to whip up the egg whites in the copper bowl, but once the job was done, the egg whites were much more stable. It seems tiny quantities of copper from the bowl react with the proteins in egg whites, forming a combination that is more robust.

Stiff peaks achieved, gently fold in the other ingredients. With wet hands, roll into 20-22 evenly sized balls and place on a greased baking sheet lined with parchment paper. Bake for 18-20 minutes at 160°C (320°F) or until just firm to the touch. These harden up when out of the oven, so beware of over-baking. Roll in icing sugar when warm, and again when cool. They are delicious hot or cold. ▮

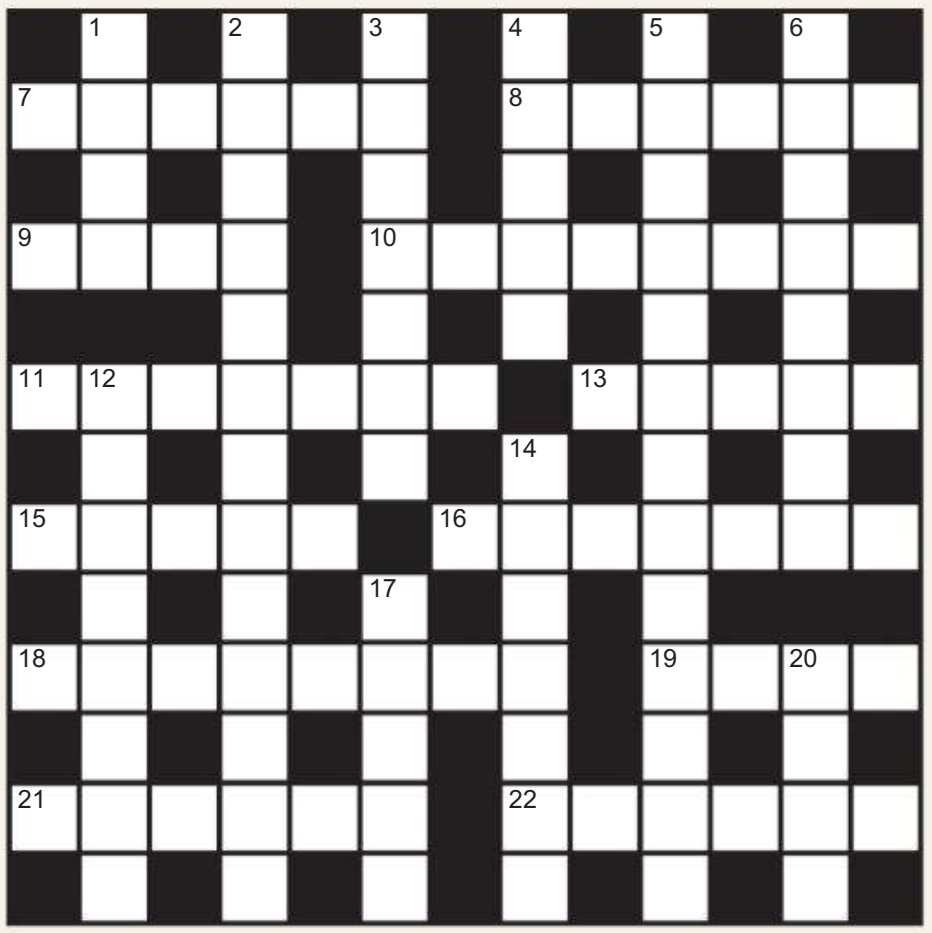
The science of baking appears monthly

These articles are posted each week at newscientist.com/maker

Next week

60-second psychology

Cryptic crossword #135 *Set by Trurl*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 He's with me, until taxi bureau mayhem ends (6)
8 Sounds like Tom's lost during conflict – that hurts severely, at first (6)
9 Means of adjusting knockback (4)
10 Object, after letter read out – it might make children uncomfortable (8)
11 Sink entrepreneur (7)
13 Not awkward or shy about sex, with other sex (5)
15 Clumsily state preference (5)
16 Clap, perhaps, to express satisfaction over something to help you get up (7)
18 Hero, given purse, lost dependency (8)
19 Curve in demonstration without mass (4)
21 Large unit in Arctic – laws broken, claims Russia (6)
22 In part of Rawalpindi, I umpired (6)

DOWN

1 Russian extremists supporting metal plant (4)
2 In major report, they set about our oddly universal origin story (3,4,6)
3 Struck with small glove (7)
4 Signal to prepare bream, filleted (5)
5 Cook hard Wuhan soy (it's the hygienic thing to do) (4,4,5)
6 Stock complaint: bounder took off noisily (5,3)
12 All-knowing cosmology leader absorbed by auroral activity (8)
14 Tool made from 50 per cent precious metal, capped with uranium-X (7)
17 French pals start to suspect it's gone wrong (5)
20 Key point made in tenth vineyard? (4)

Our crosswords are now solvable online
newscientist.com/crosswords

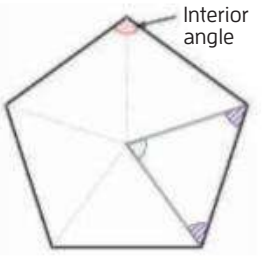
Quick quiz #251
set by Bethan Ackerley

1 Which is thought to be the most common type of asteroid: M-type, C-type or S-type?
2 True sparrow species are members of what genus?
3 The brightness of which star cluster aided the Eddington experiment of 1919?
4 Alzheimer's disease is thought to be linked to the build-up of beta-amyloid and which other protein?
5 In anatomy, the spot where two structures cross is known as what?

Answers on page 47

BrainTwister
set by Alison Kiddle
#19 Angular arrangements

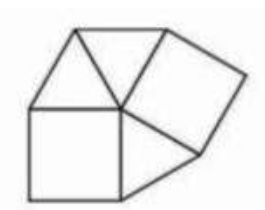
A regular polygon is a shape with at least three straight sides where all the sides are the same length and all the interior angles are equal.



Knowing that a full turn is 360° and the angles in a triangle add up to 180°, can you use this diagram to work out the size of the interior angles in this regular pentagon? Hint: an interior angle is made up of two adjacent angles from the outer corners of the triangle.

Can you use the same idea to find a general way to calculate the interior angle of any regular polygon?

It is possible to arrange regular polygons around a point so they meet without leaving any gaps. Below is one such arrangement, using squares and equilateral triangles.



There are other ways to arrange regular polygons so they meet exactly at a point. How many can you find? What is the maximum number of sides a polygon in such an arrangement can have?

Solution next week

Healthy appetite

Other than humans, animals just eat what they find, as they find it – no cooking, no washing. Why aren't they vomiting all the time?

Nikola Stojanovic
Leskovac, Serbia
Animals, particularly wild ones, have digestive systems that are adapted to handle raw and uncooked foods, which are their natural diet. Their stomach acidity is usually higher, enabling them to break down raw meat, bones and other tough materials more efficiently, as well as killing harmful bacteria.

Mike Follows
Sutton Coldfield, West Midlands, UK
Carnivores can suffer from food poisoning, but there are several reasons why they are less susceptible than we are.

For one, fresh meat is much less likely to be contaminated with bacteria. Also, carnivores have a simpler, smoother and shorter digestive tract compared with omnivores and especially herbivores. This means that food spends less time passing through their guts and any bacteria will have less time to multiply to a level that would make them ill.

"The stomach acid of some vultures can dissolve bone – indeed, the bearded vulture, or ossifrage, feeds almost exclusively on bone"

Besides, animals tend to avoid eating the digestive tract and other parts of their prey that are more likely to be contaminated with bacteria. Finally, carnivores have stronger stomach acids, which are more likely to kill any pathogens that might be present.

Indeed, some animals like vultures, which specialise in eating carrion, have particularly strong stomach acids. While other scavengers can spread pathogens far and wide via their faeces, vultures are the ultimate clean-up crew because pathogens will die before they are passed out in their guano. The stomach acid of some vultures can even dissolve bone. Indeed, the bearded vulture (*Gypaetus barbatus*), also known as the ossifrage or "bone-breaker", feeds almost exclusively on bone.

While individual animals can succumb to poison, a species can adapt to tolerate it or learn to avoid it. The cane toad (*Rhinella marina*), which is poisonous, was introduced to Australia in 1935 to control beetle pests that were damaging sugarcane crops. The Australian freshwater crocodile (*Crocodylus johnstoni*) has adapted to consume only the hind legs, which are free of poison.

In contrast, our supply of food is increasingly sanitised; as well as making the food more nutritious, cooking destroys many pathogens that remain. Our reduced exposure to pathogens weakens our immunity and makes us more susceptible to food poisoning when we do consume contaminated food. This is exacerbated by the fact that, as omnivores, our digestive tracts are longer than those of carnivores, which affords pathogens ample time to multiply to levels that can make us ill.

Garry Trethewey
Arkaroola Wilderness Sanctuary, South Australia
I once lived in an ashram in a Western country. Everyone was nominally vegan, but with varying degrees of compliance. Occasionally, a bout of diarrhoea and vomiting would sweep the place, and we noticed the intensity was in proportion to the degree of veganism – the most compliant had the worst of it. Eventually, someone noticed mouse poos in the rice jar. Once it was mouse-proofed, we had no further bouts.

I am now involved with conservation and habitat restoration, as well as dealing with introduced predators. We find it easy to bait foxes and wild dogs, but not cats. Canids have long noses, full of smell receptors, and can find smelly rotten meat from a distance and safely eat it. Cats, on the other hand, are visual stealth predators that sneak up and attack live animals – and don't tolerate more than minimally rancid meat.

Shelton Harlow
Via Facebook
Ever had a dog? They vomit a lot...

PATRICIO NAHUELHUAL/ALAMY

This week's new questions

Tea time **Will my tea cool more quickly if it is left out at room temperature, or if my hands are cupped around the mug?** ***Rafi Berke****, London, UK*

Does putting your hands around a mug of tea make it cool down quicker or more slowly?

Frozen in place **Why do victims of violent attacks sometimes take no immediate action, and how can we learn to react appropriately?** ***Peter Slessenger****, Reading, Berkshire, UK*

Going north

Earth's north magnetic pole is moving from Canada towards Siberia. Has there been a noticeable effect on migrating animals that sense the geomagnetic field as a navigation aid?

Mark Thompson
Tewkesbury, Gloucestershire, UK
For any animal that is using a magnetic field for long migrations, they may be using it only to detect deviations from their planned route. It has been proposed that migratory birds, for example, have at least three different compasses at their disposal: one allows them to extract information from the position of the sun in the sky, another uses the patterns of the stars at night and the third is based on Earth's magnetic field.

Once they are under way, their magnetic sense would help keep them on the course planned using their other senses, again not because they were born with

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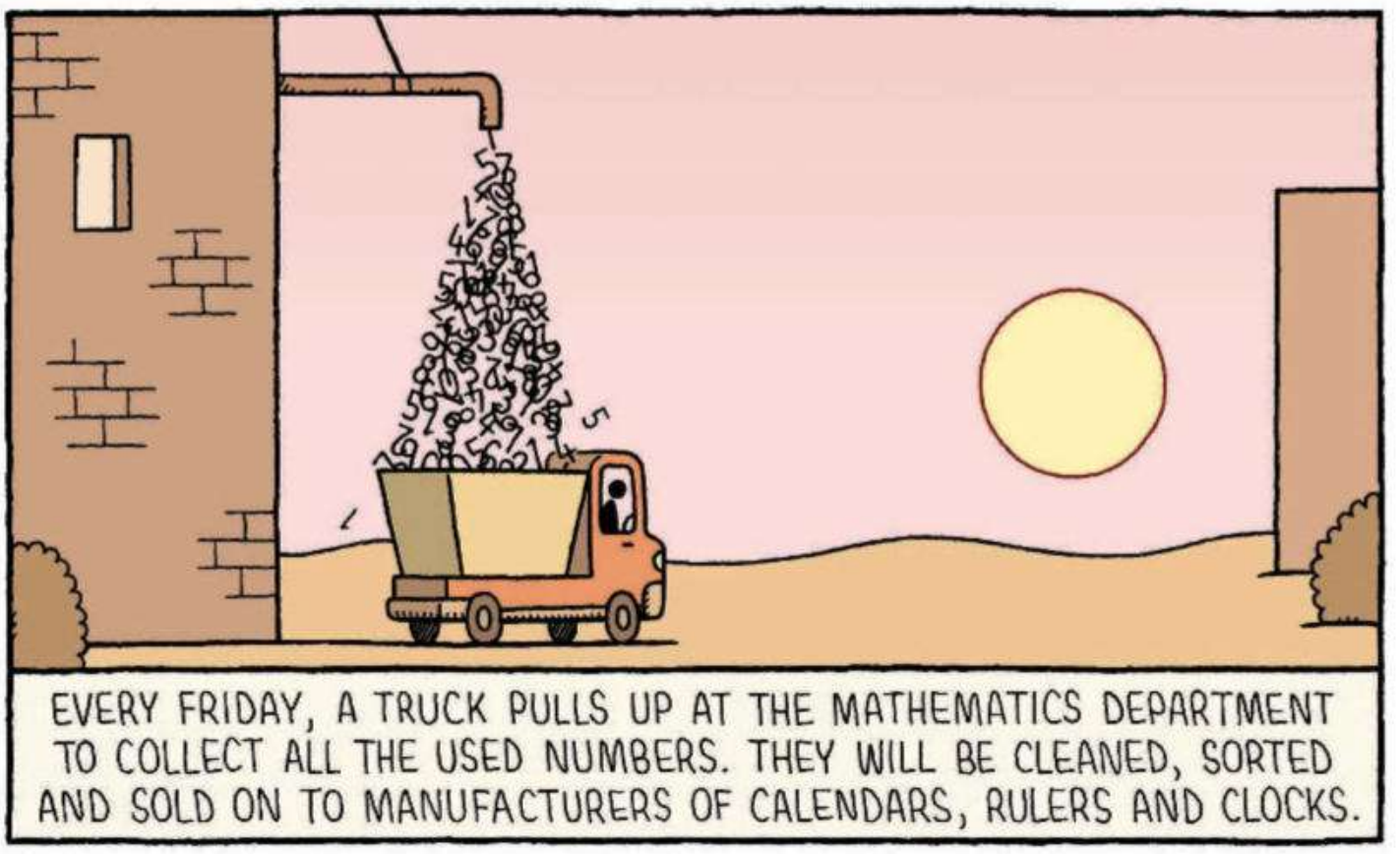
Tom Gauld
for New Scientist


EVERY FRIDAY, A TRUCK PULLS UP AT THE MATHEMATICS DEPARTMENT TO COLLECT ALL THE USED NUMBERS. THEY WILL BE CLEANED, SORTED AND SOLD ON TO MANUFACTURERS OF CALENDARS, RULERS AND CLOCKS.

a genetic geomagnetic map of Earth in their brain, but rather by the simpler mechanism of steering to minimise changes in their orientation relative to the field.

Thus, a slow geomagnetic movement wouldn't be a problem – the migrating animal wouldn't care at all which way the field is pointing or whether it used to be different. They would only care that they stayed in the same orientation to the field that they sensed when they began.

We know Earth's magnetic field has flipped several times during the evolution of birds, and there is no evidence this has caused mass extinction events.

Steve Agar
Nine Banks, Northumberland, UK

Having for many years considered how ludicrous some bird migrations are, I do wonder whether they have been victims of evolution acting more slowly than the rapid "flips" of Earth's magnetic field from time to time.

Rather than weeks-long transoceanic and transcontinental flights, perhaps the poor blighters were originally simply setting off on a short sojourn south to feeding or breeding grounds far closer to home.

"I couldn't resist the temptation to let my laser cutter loose on some bread, after a correspondent speculated about this"

Best thing since

What is the best way, and best knife to use, to minimise crumbs when slicing bread, particularly wholemeal? (continued)

Hubert van Hecke
Santa Fe, New Mexico, US

Having access to a 150-watt carbon dioxide laser cutter, I couldn't resist the temptation to let it loose on some bread, something that had been speculated about as a possible answer to this question.

I had a "Powerseed" loaf from the brand Dave's Killer Bread, and at 30 per cent power my laser cutter went cleanly through a slice at 20 millimetres per second cutting speed, leaving the edges slightly browned and not a single crumb. The bread smelled burnt, not toasted.

I didn't attempt to cut through a whole loaf of our home-baked bread, since the laser beam would diverge over the height of the loaf and would be badly out of focus towards the bottom of the loaf. ▮

HUBERT VAN HECKE

Answers

Quick quiz #251 *Answers*

1 C-type
2 *Passer*
3 The Hyades
4 Tau
5 A chiasm

Quick crossword #157 *Answers*

ACROSS 1 Von Karman**,**
6 Topaz, **9** Niobium,
10 Rhodium, **11** Start,
12 Steel wool, **13** Electrode,
15 Resus, **16** Cache, **18** Silicosis,
20 Exosphere, **23** Corus,
25 E-reader, **26** Epiderm,
27 T-rail, **28** Cryogenic

DOWN 1 Venus, **2** Neonate,
3 Aristotle, **4** Mumps, **5** Nurse cell,
6 Troll, **7** Poisons, **8** Zymolysis,
13 Excrement, **14** Obstetric,
15 Recycling, **17** Cholera,
19 Surgeon, **21** Pedal,
22 Emery, **24** Sumac

#18 The arithmetical two-step *Solution*

From 42, we can subtract 2 and divide by 4, or divide by 6 and add 3. You can get to 10 in two steps for all numbers from 11 to 30. E.g. for 11, you undershoot and then come back by subtracting 2 and adding 1. Numbers from 12 to 28 can all reach 10 using two subtractions. For 29 you can subtract 9 and divide by 2. For 30 you can divide by 2 and subtract 5. For numbers above 30, if they aren't a multiple of 10 you can subtract a number to make a multiple of 10, then divide to get 10. Multiples of 10 that are also a multiple of 20 can be divided by 2 then divided again to get 10, and similarly for multiples of 30. This leaves 50 and 70, which can reach 10 in one step but not two.

Nest in mouth

Curious items lurk unnoticed in large museums. The photo below shows one of them: a bird's nest seated in the mouth of a large, ancient, carved stone human face.

Feedback recently had the joy of accompanying the director of one of the Netherlands's great natural history museums when he paid a first visit to the National Roman Museum, an archaeology repository that occupies what once were Rome's great ancient thermal baths. The previous day, a professor from University College London had visited the same site, noticed this unusual object-inside-an-object – and alerted his Dutch colleague.

The professor remarked that it was hanging high on a wall in a dusty section of a large, open-air garden known as Michelangelo's Cloister. It looked, he said, as if nobody had even glanced at it in recent times. Surely, he said, if the museum had become aware that a bird had homesteaded in that historical mask, the nest would have been removed immediately.

The Dutch museum director suspected it was the work of an Italian sparrow (*Passer italiae*) and hoped to acquire the deserted nest for his museum, in lieu of having the Roman museum destroy or discard it. He inquired of an official, who was obviously a little shocked at hearing of the nest's existence.

MARC ABRAHAMS

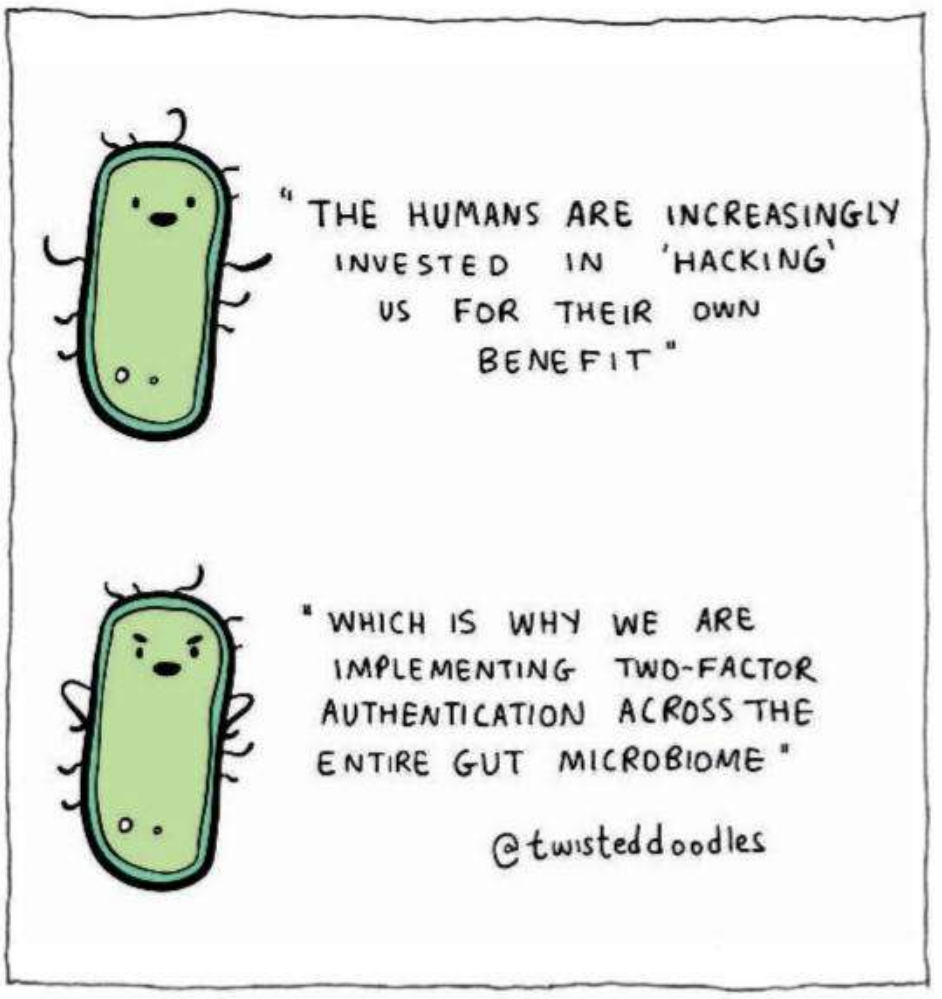
The official grew visibly sad, and said: "We have bigger problems. We also have cats inside."

Several higher levels of official were consulted, each quickly deciding that everyone would be delighted if the Dutch visitor would remove the nest. They sent for a ladder. This triggered the arrival not of a ladder, but of a still higher-level official. He instantly expressed what the non-Italian visitors interpreted to be neck-wringing rage. Not a twig, he declared, not a pebble, must ever leave his museum.

And so the nest remained in the mask on the wall of the cloister.

Feedback would now enjoy a report from someone who ventures to visit the northernmost corner of Michelangelo's Cloister to observe whether the nest is still there.

Twisteddoodles *for New Scientist*


"THE HUMANS ARE INCREASINGLY INVESTED IN 'HACKING' US FOR THEIR OWN BENEFIT"
"WHICH IS WHY WE ARE IMPLEMENTING TWO-FACTOR AUTHENTICATION ACROSS THE ENTIRE GUT MICROBIOME"
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Little big battery

In the spirit of "whatever they can do I can do better", Espen Gaarder Haug sent us a copy of the study he and Gianfranco Spavieri published in *High Energy Density Physics*: "The micro black hole cellular battery: The ultimate limits of battery energy density".

Haug says: "I see you wrote about the Schwarzschild Black Hole Battery (13 January 2024). [Our paper] goes a few steps forward: 'a battery weighing just one kilogram could provide approximately 470 million times the energy of the most efficient 200-kilogram lithium battery at the time of writing'."

The paper explores a possible future: "[This involves] a cellular battery composed of micro black holes... [It] is not inconceivable that battery technology development could follow a trajectory similar to that of computer technology... [It] is possible that battery efficiency could double or even quadruple every few years following different types of breakthroughs."

Haug displays a fascination for potency and value at tiny extremes. In 2020, he published a solo paper about "the smallest possible money unit". He wrote: "we demonstrate that there is an absolute physical limit on how small the smallest money unit can be... [It] seems to be directly linked to the smallest possible energy unit needed to store one bit."

This is small stuff. No one is thinking universally big. As yet, there are no published papers by anyone identifying the largest possible electrical battery or money. (None, anyway, has come to Feedback's attention.)

Whodunnit?

"Whodunnit?" is a question answered, starkly, in every published research study. The answer is: the authors. The authors dunnit. The authors wrote the study. But a new study tries to answer a jarringly different question: who didn't do it? How many distinguished persons listed as authors are not, in fact, authors?

***Scientific Reports* published this real-academic-life detective story. The detectives try to ascertain how often academic big shots grab a full share of official authorship credit for research work they did not do.**

This is potentially nasty stuff. "The practice of [automatically] listing a senior member(s) of a department, who did not qualify for authorship, as a co-author on all or most submitted articles," the sleuths explain, "can be an efficient way to boost the scientific output of these individuals." After considering the evidence, the team concludes that the goings-on "may be common in the health sciences, with those admitting to this practice finding it unjustified in most cases".

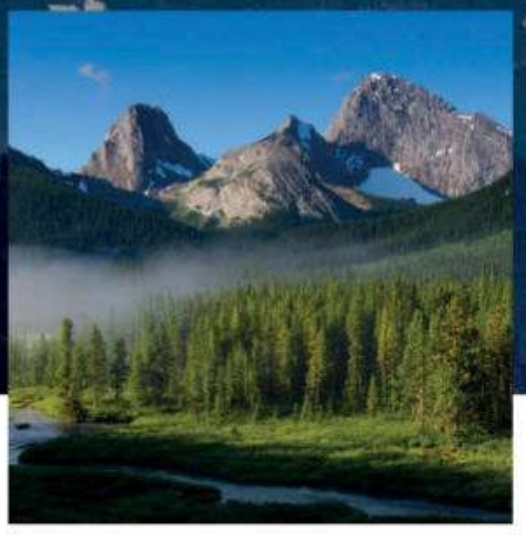
Feedback notes two colourful, minor facts about this study. First, disappointingly, there is no direct indication as to whether any of its authors are senior members of a department. Second, reassuringly, the paper specifies that "all 5 authors... participated substantially in all research steps". ▮

Marc Abrahams

Discovery Tours

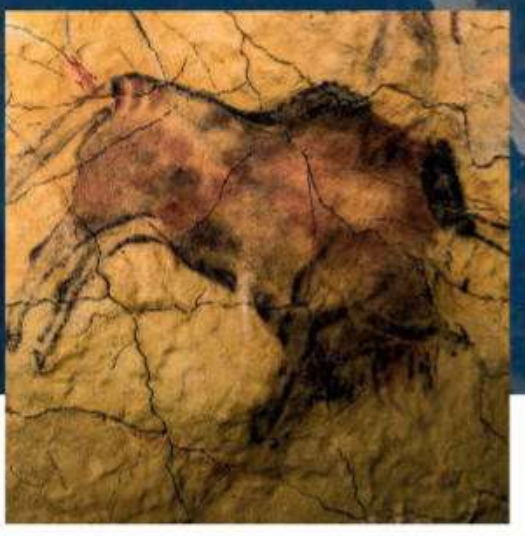
NewScientist

Tours departing soon!



The Rockies and the Badlands: Geology and dinosaurs in Canada

17 June 2024 | 7 days



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